US010016804B2

(12) **United States Patent**
Tanaka et al.

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(45) **Date of Patent: Jul. 10, 2018**

(54) **HAT-SHAPED CROSS-SECTION COMPONENT MANUFACTURING APPARATUS AND MANUFACTURING METHOD**

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(73) Assignee: **NIPPON STEEL & SUMITOMO METAL CORPORATION**, Tokyo (JP)

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PCT Pub. Date: **Apr. 30, 2015**

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(51) **Int. Cl.**
B21J 5/02 (2006.01)
B21D 22/26 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***B21J 5/02*** (2013.01); ***B21D 22/26*** (2013.01); ***B21D 24/04*** (2013.01); ***B21D 45/02*** (2013.01)

(58) **Field of Classification Search**
CPC B21J 5/02; B21J 5/025; B21J 13/02; B21J 13/025; B21J 13/04; B21J 13/08;
(Continued)

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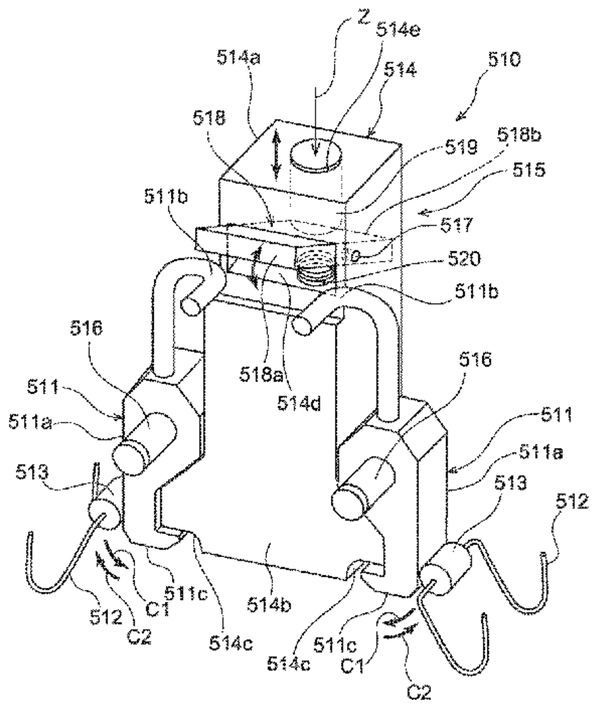
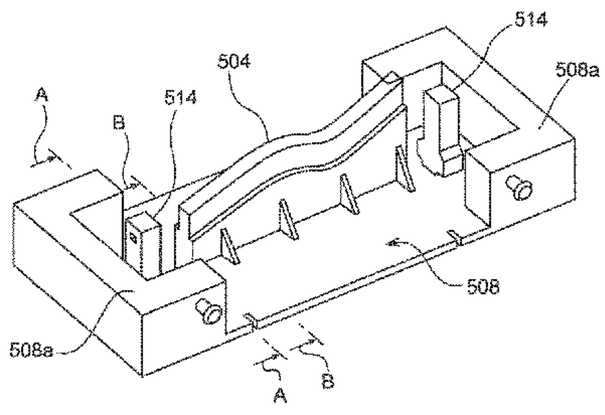
Primary Examiner — R. K. Arundale
Assistant Examiner — Pradeep C Battula
(74) *Attorney, Agent, or Firm* — Birch, Stewart, Kolasch & Birch, LLP

(57) **ABSTRACT**

A hat-shaped cross-section component manufacturing apparatus includes: a die that includes a forming face that presses both side portions of a metal stock sheet; a punch that includes a forming face that presses a central portion of the metal stock sheet; a pad that includes a forming face that presses and grips the central portion of the metal stock sheet against the punch; and a blank holder that includes a forming face that presses and grips the both side portions of the metal stock sheet against the die. The hat-shaped cross-section
(Continued)





component manufacturing apparatus further includes a pressure limiting device configured including a floating block that moves together with the blank holder when forming of a curving component has been completed, that is interposed between the pad and the blank holder, and that limits pressing of the formed curving component between the pad and the blank holder during demolding.

7 Claims, 44 Drawing Sheets

(51) **Int. Cl.**
B21D 24/04 (2006.01)
B21D 45/02 (2006.01)

(58) **Field of Classification Search**
CPC B21D 22/02; B21D 22/10; B21D 22/22; B21D 22/26; B21D 24/02; B21D 24/10; B21D 24/12; B21D 24/14; B21D 45/02
See application file for complete search history.

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* cited by examiner

FIG.1A

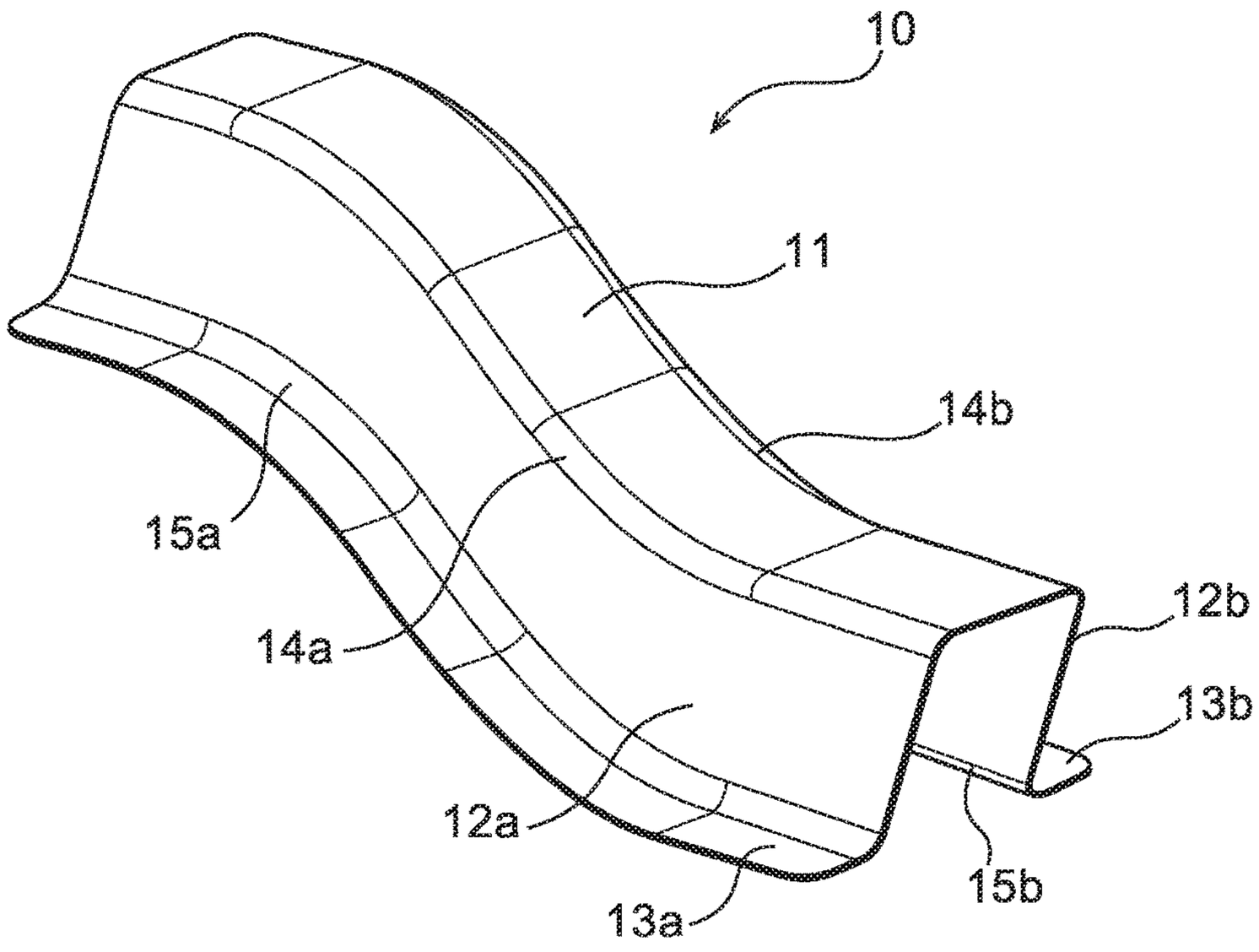
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FIG.1B

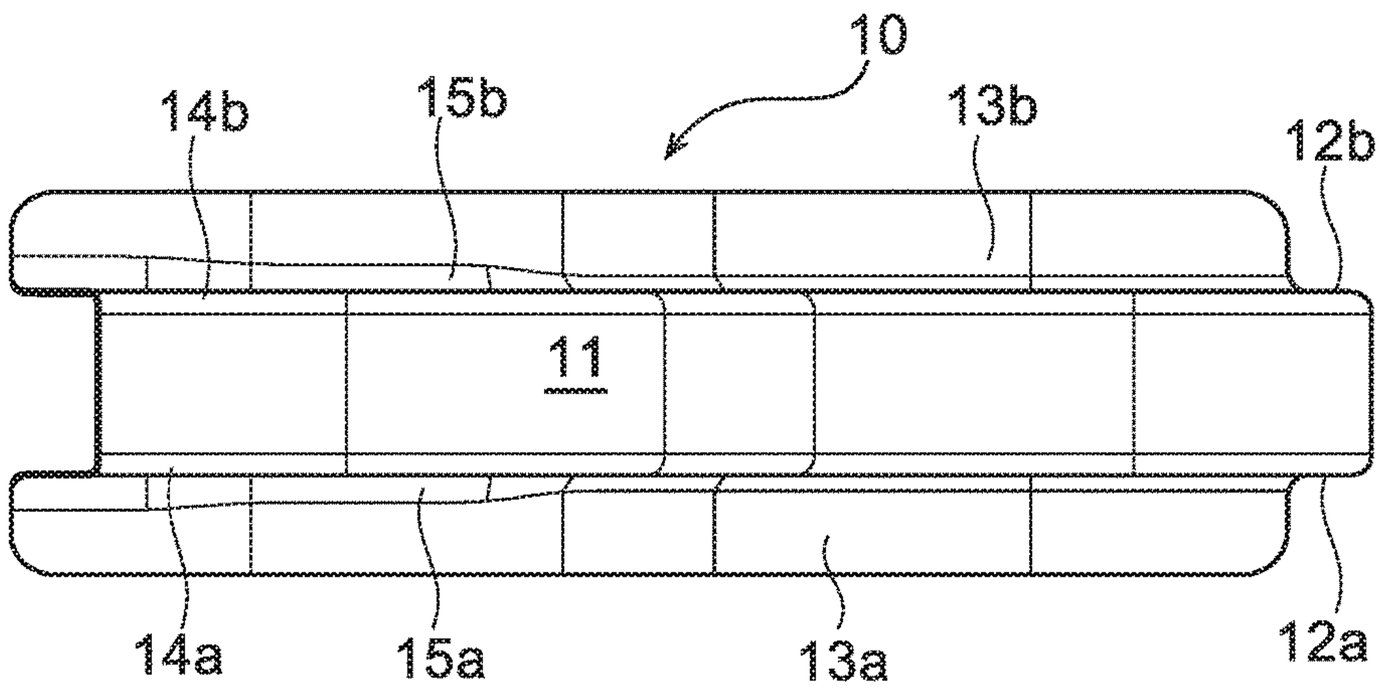
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FIG.1C

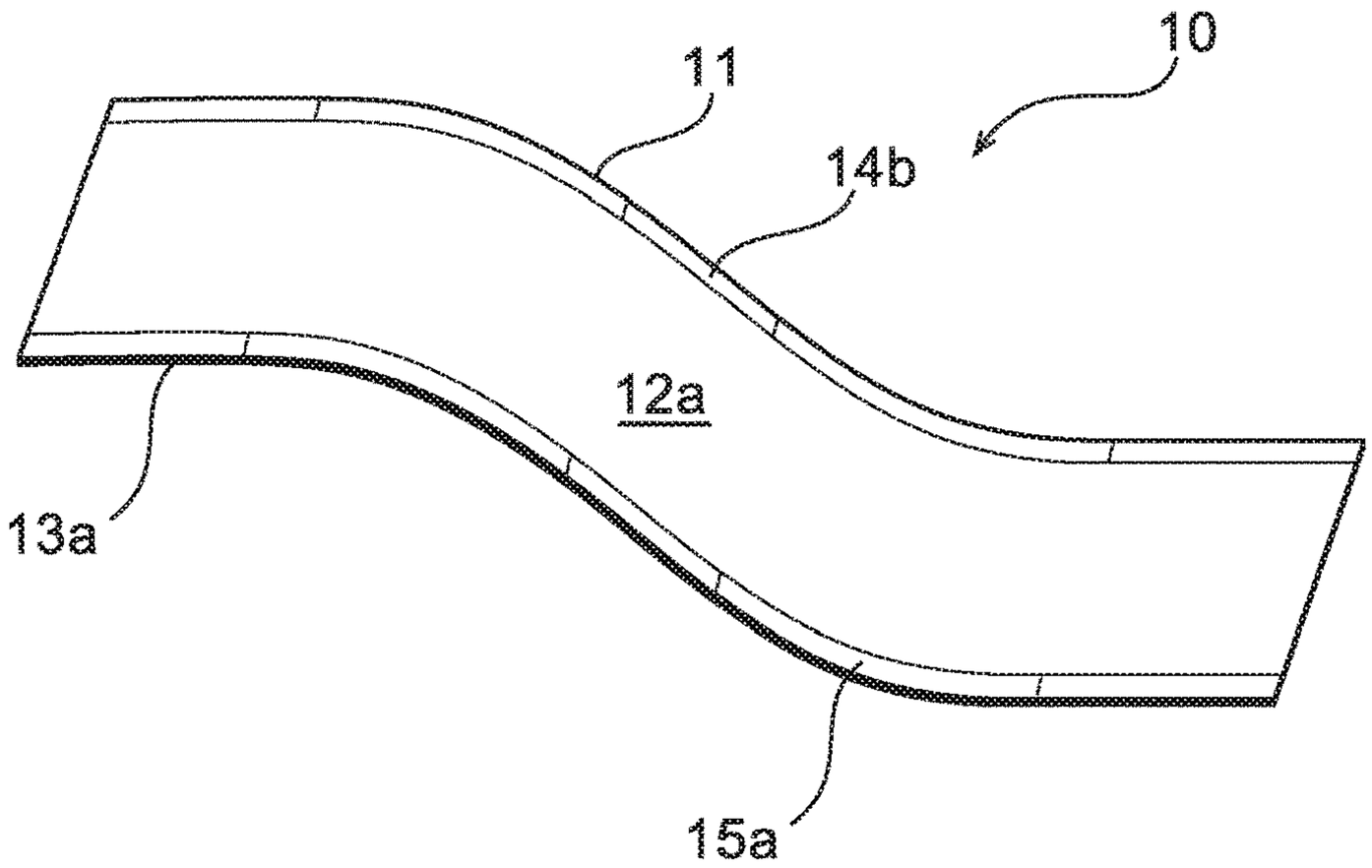

FIG.1D

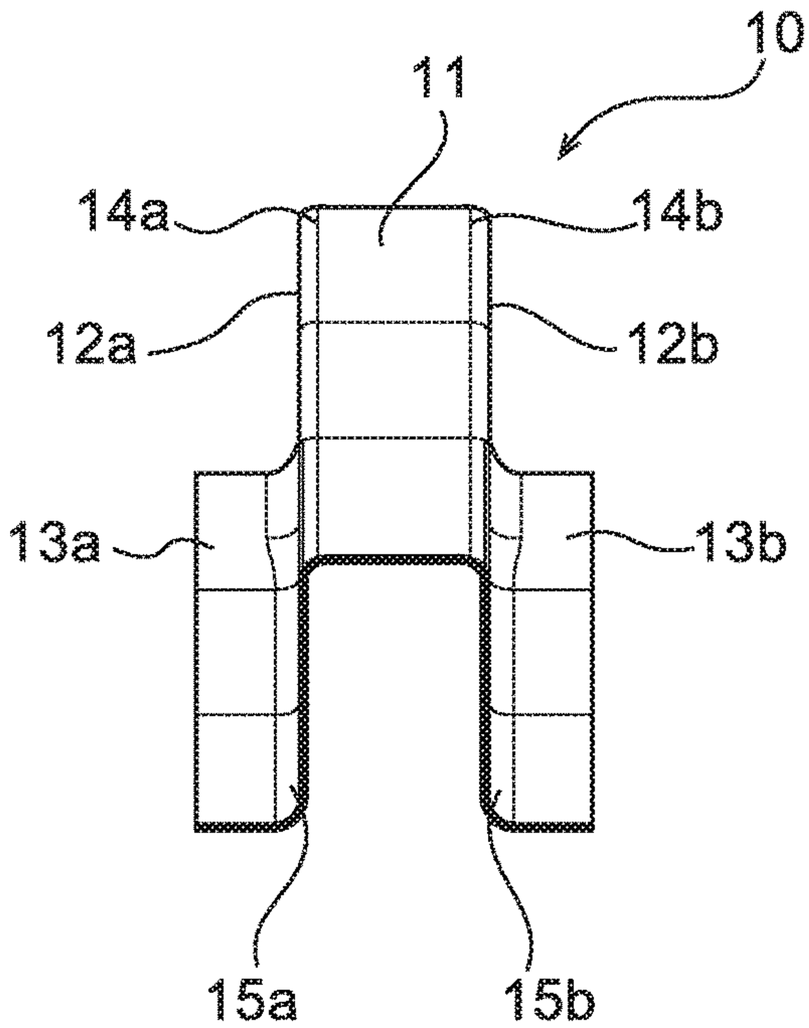

FIG.2

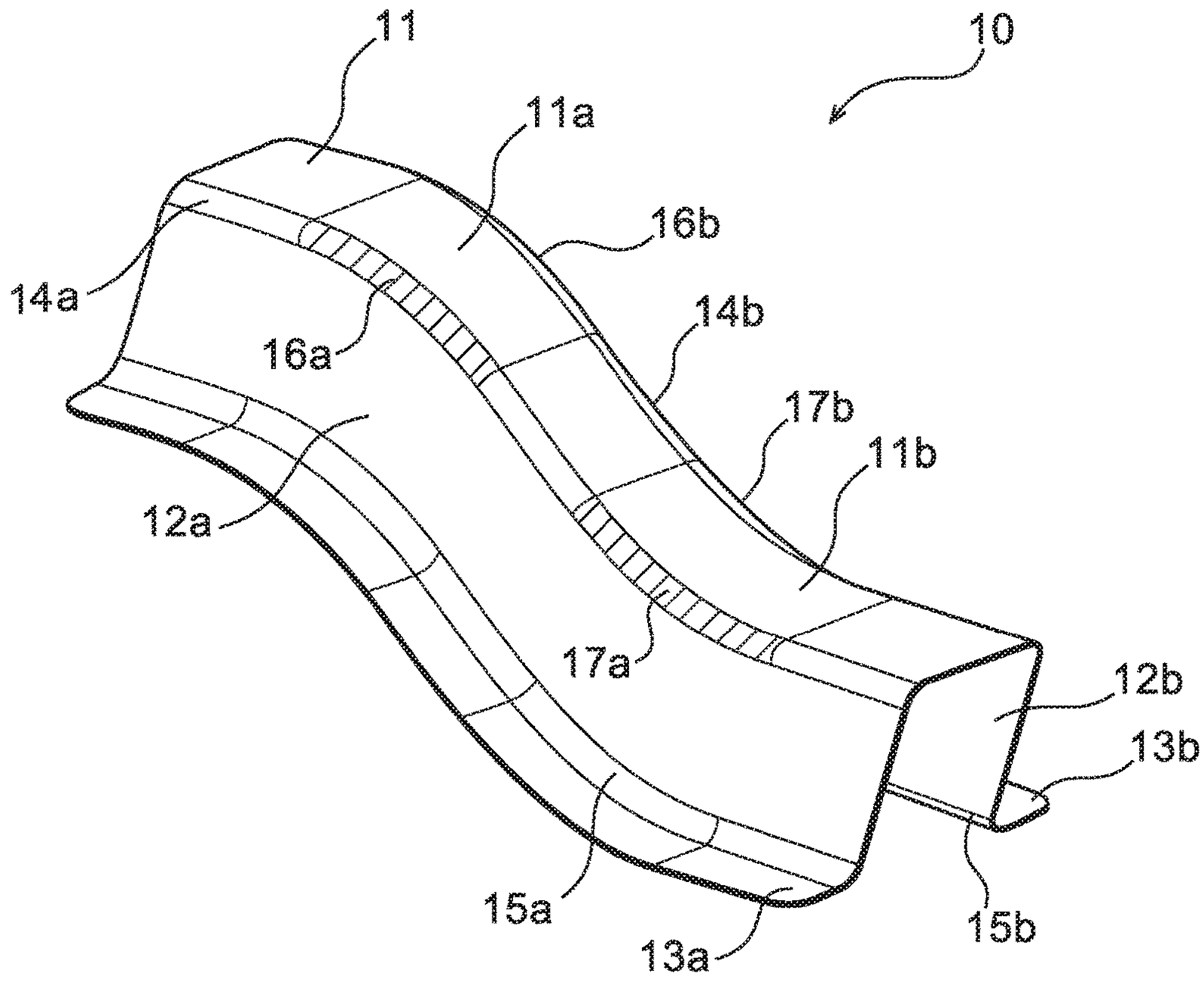

FIG.3A

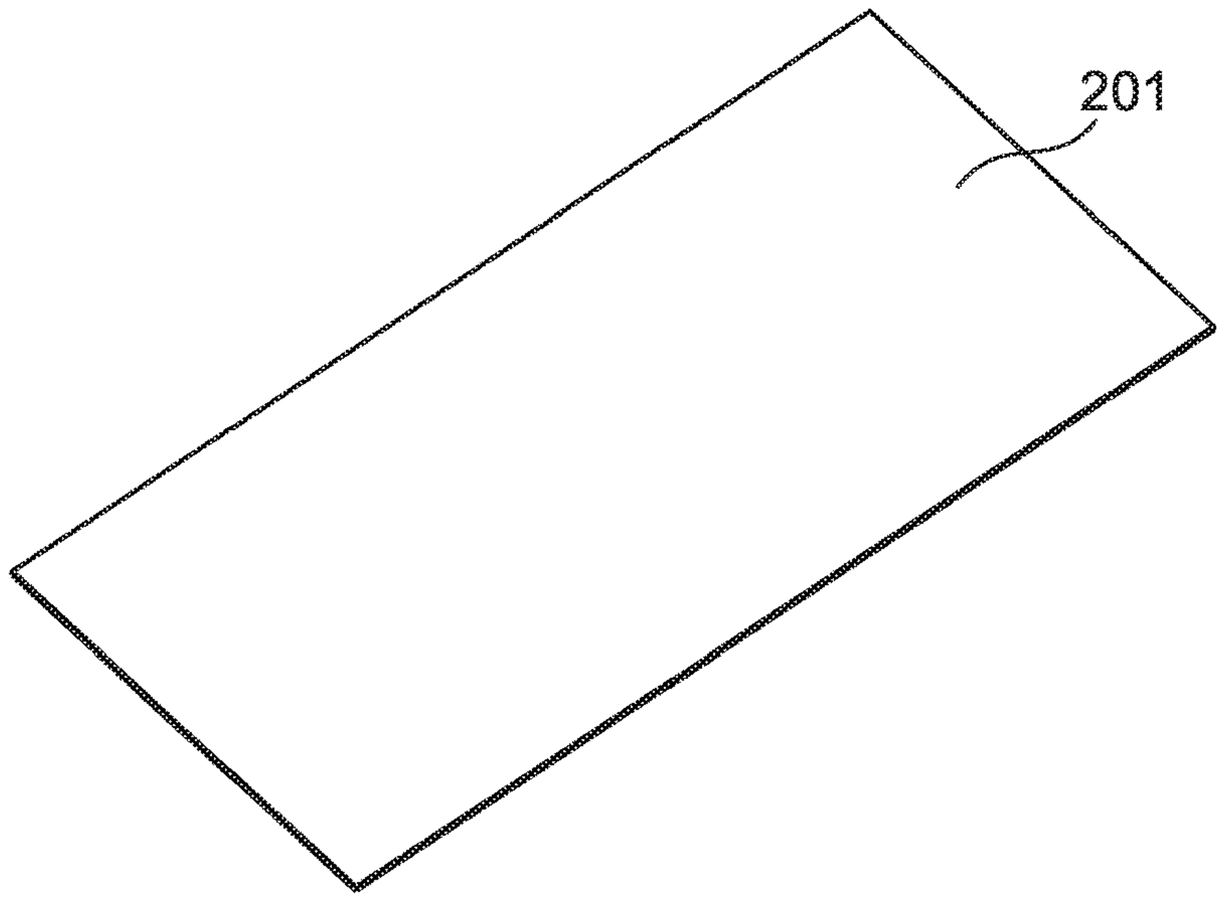

FIG.3B

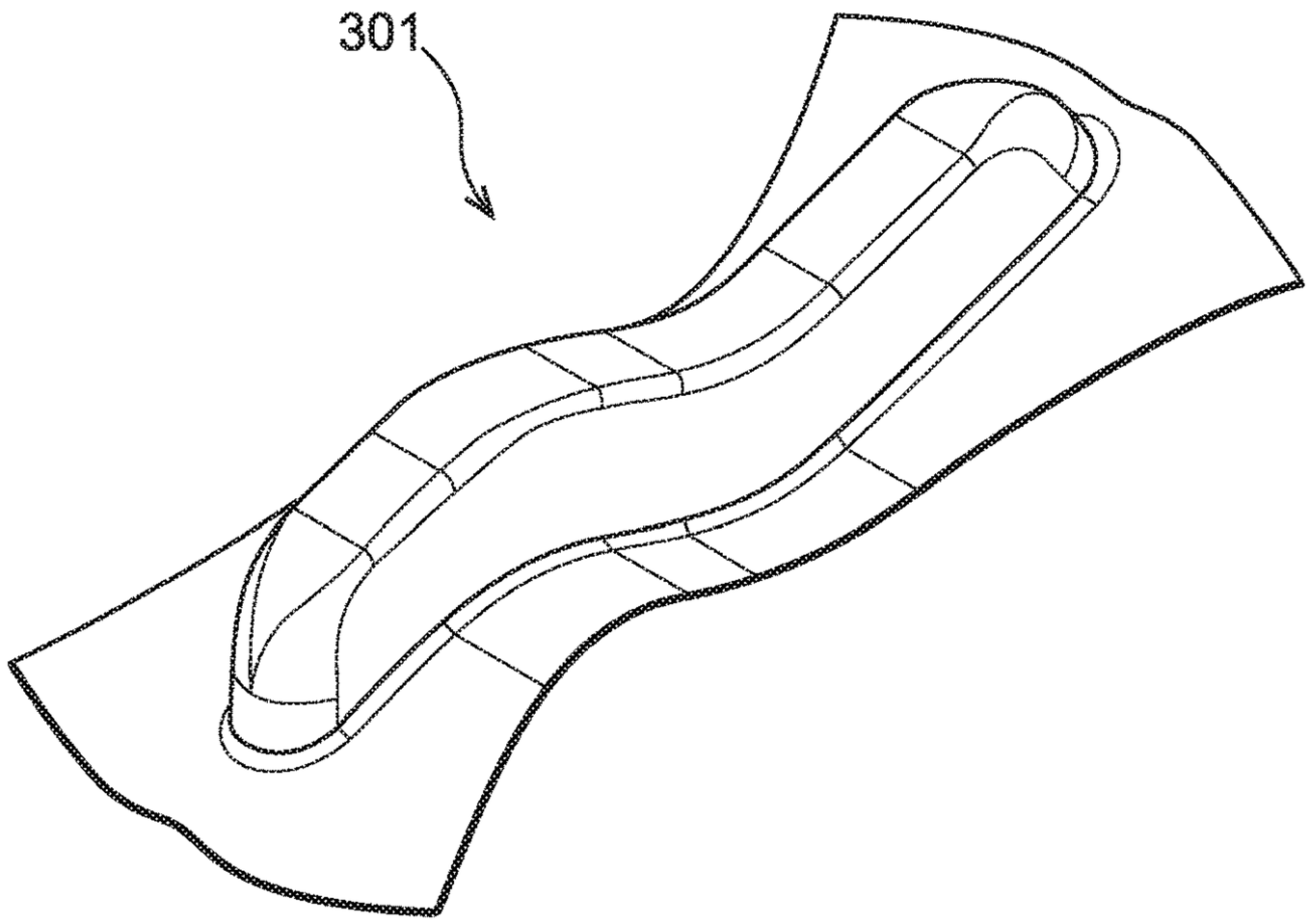

FIG.4

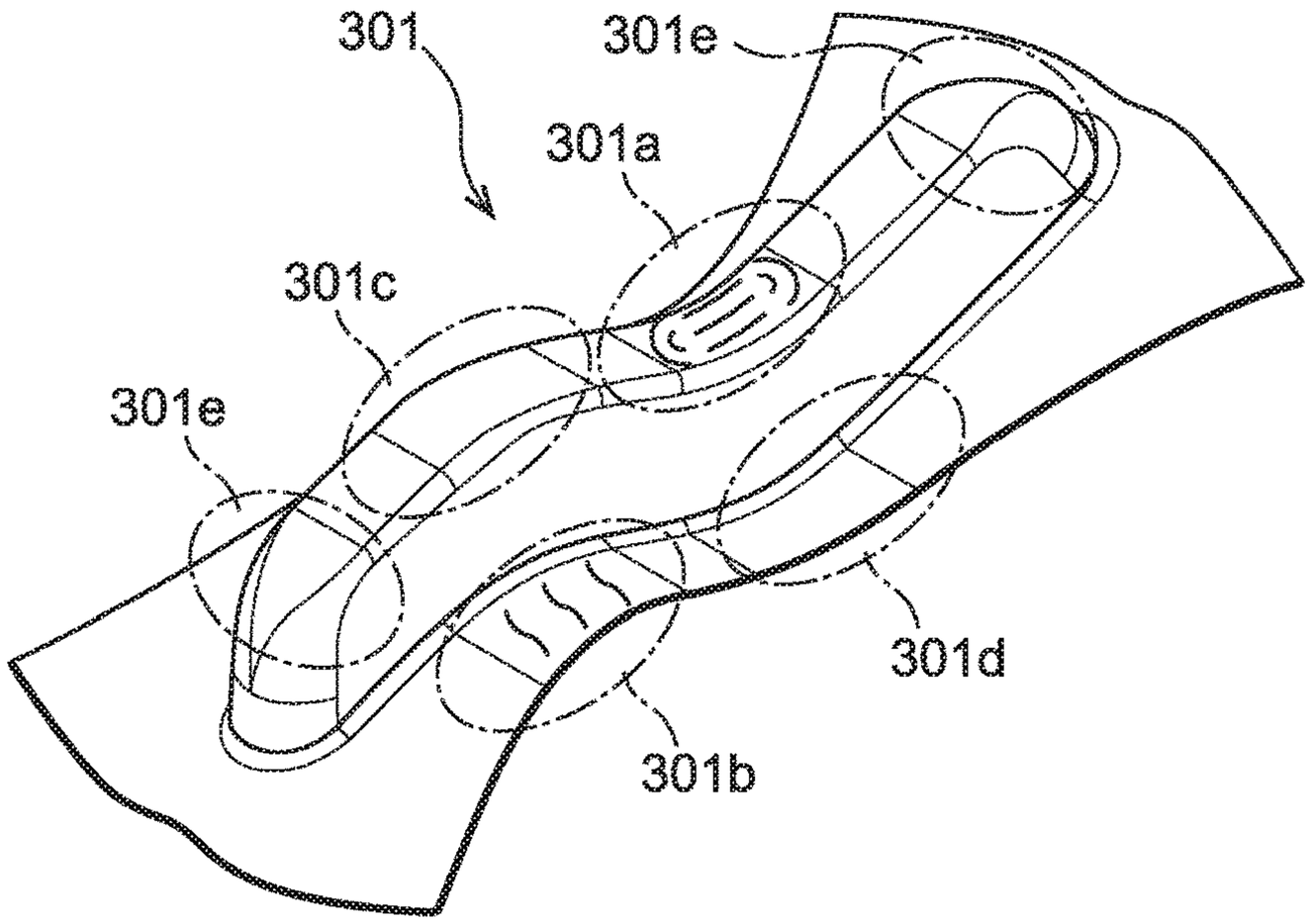
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FIG.5

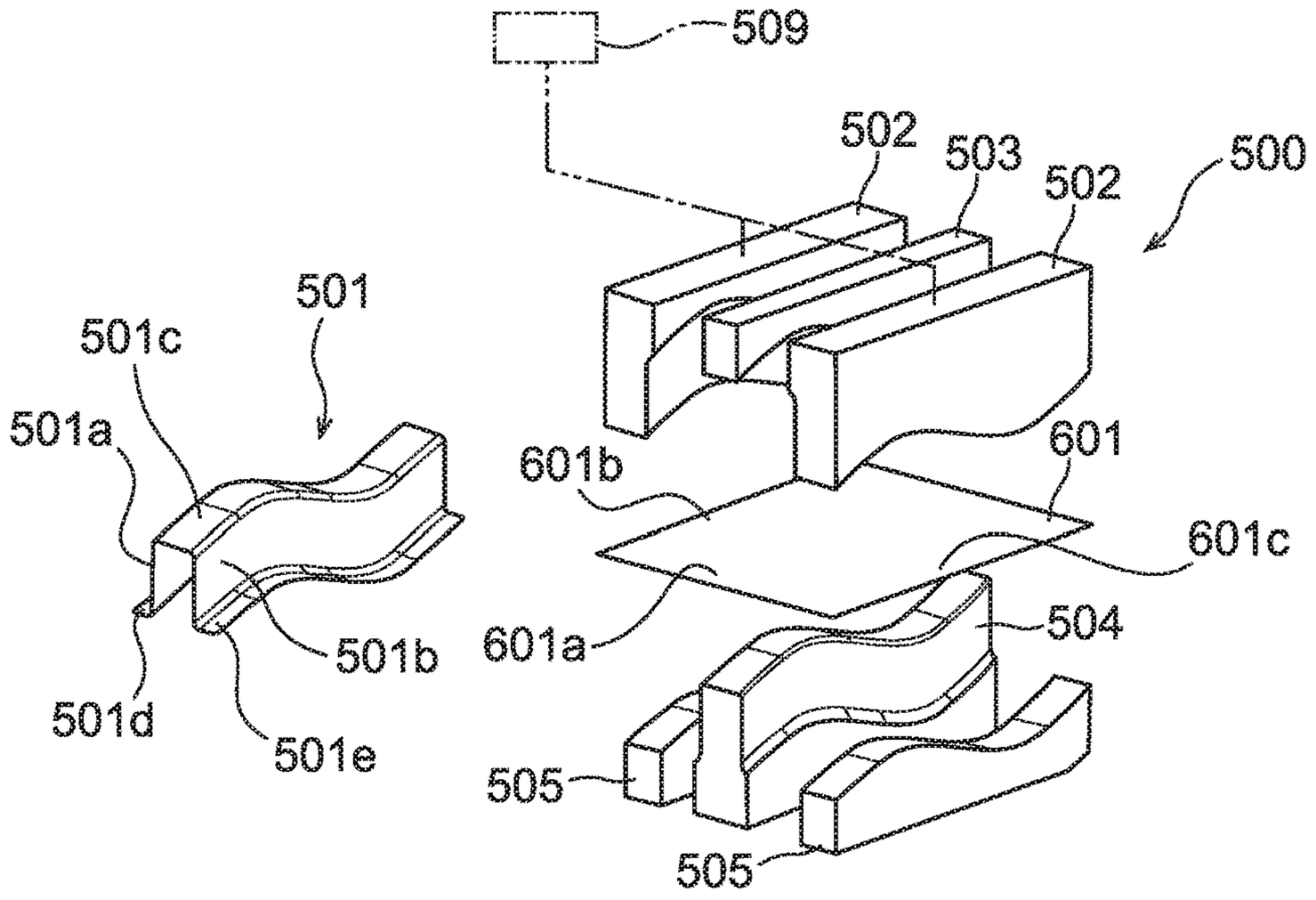
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FIG.6A

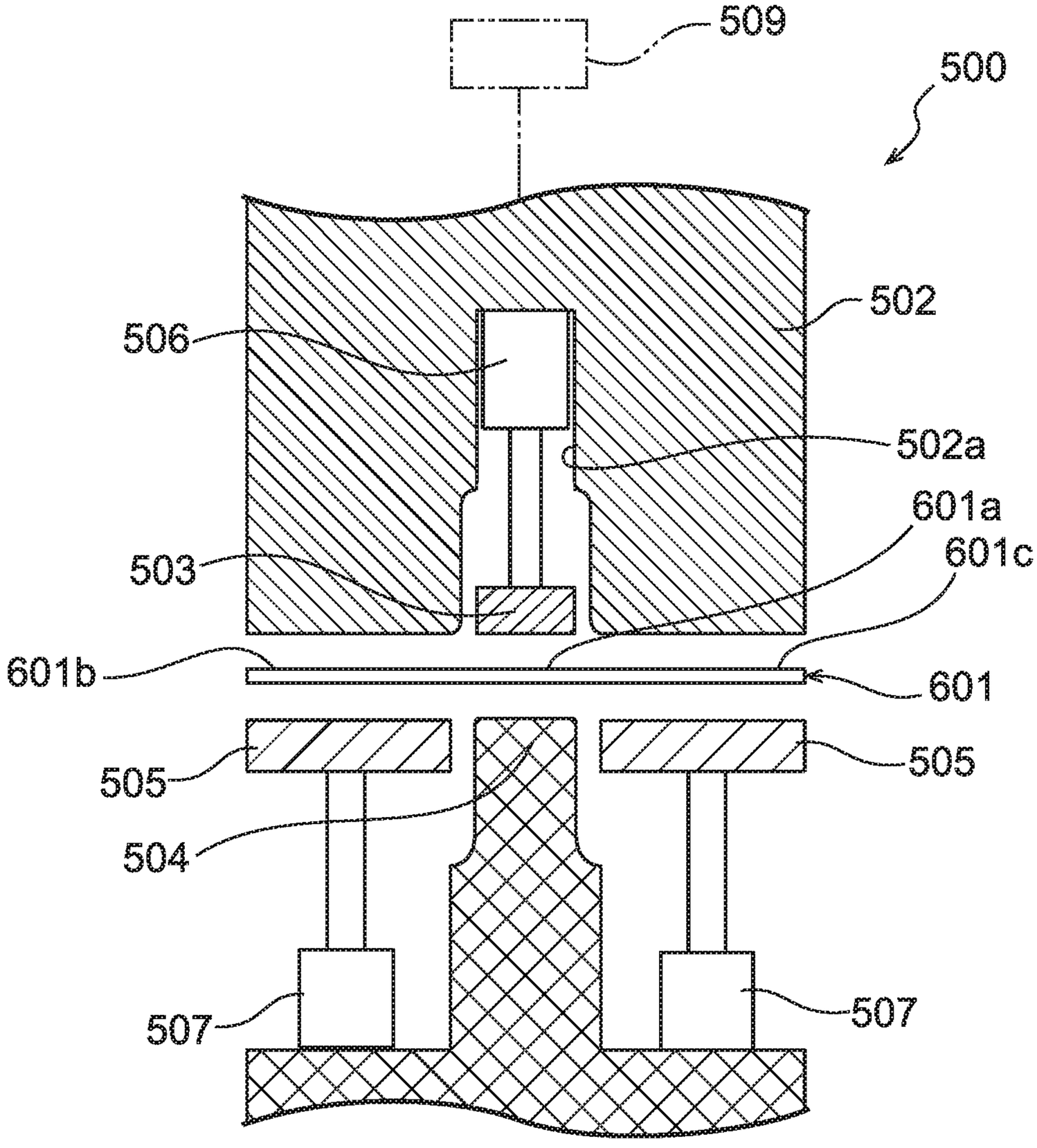

FIG.6B

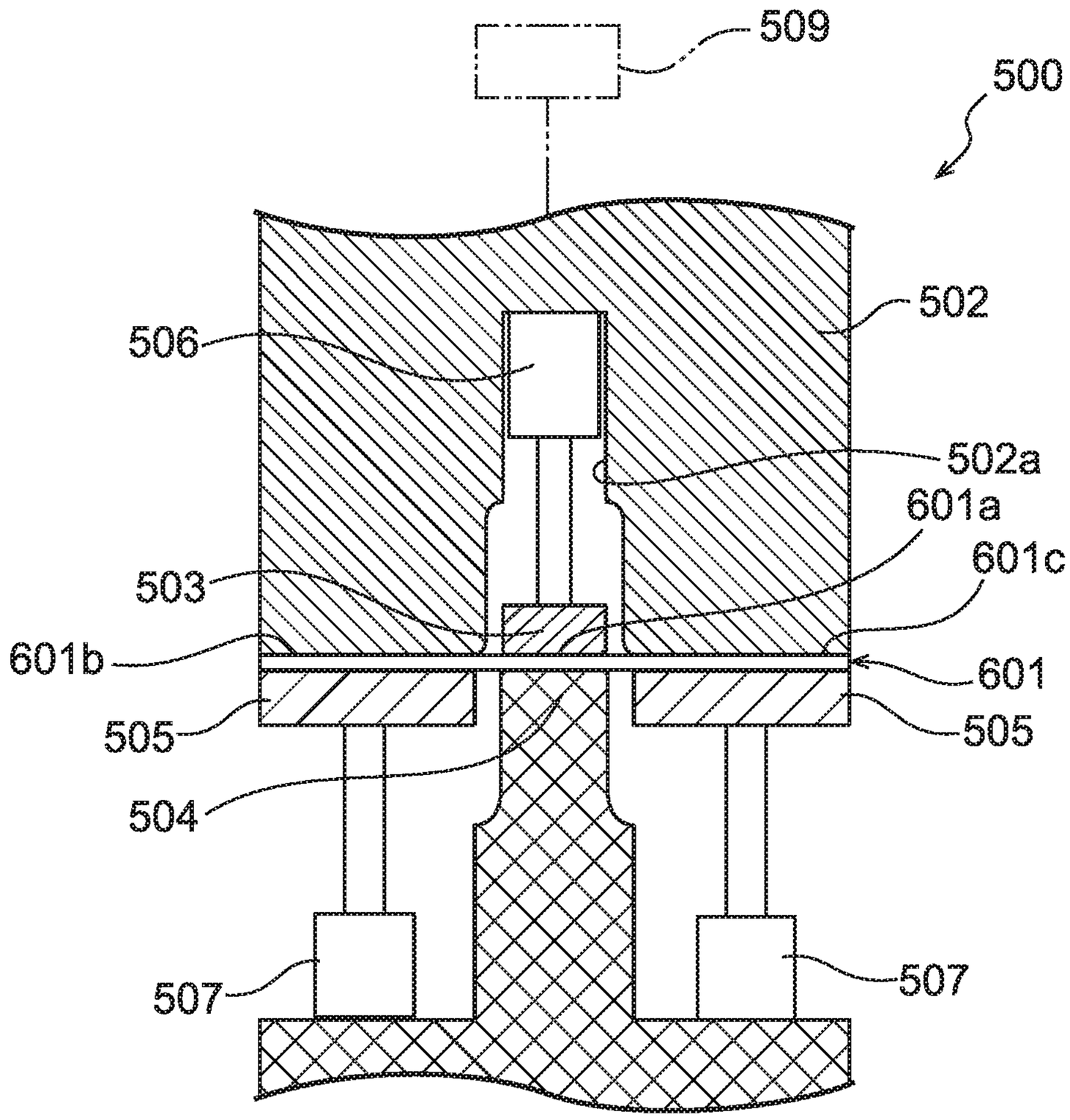

FIG.6C

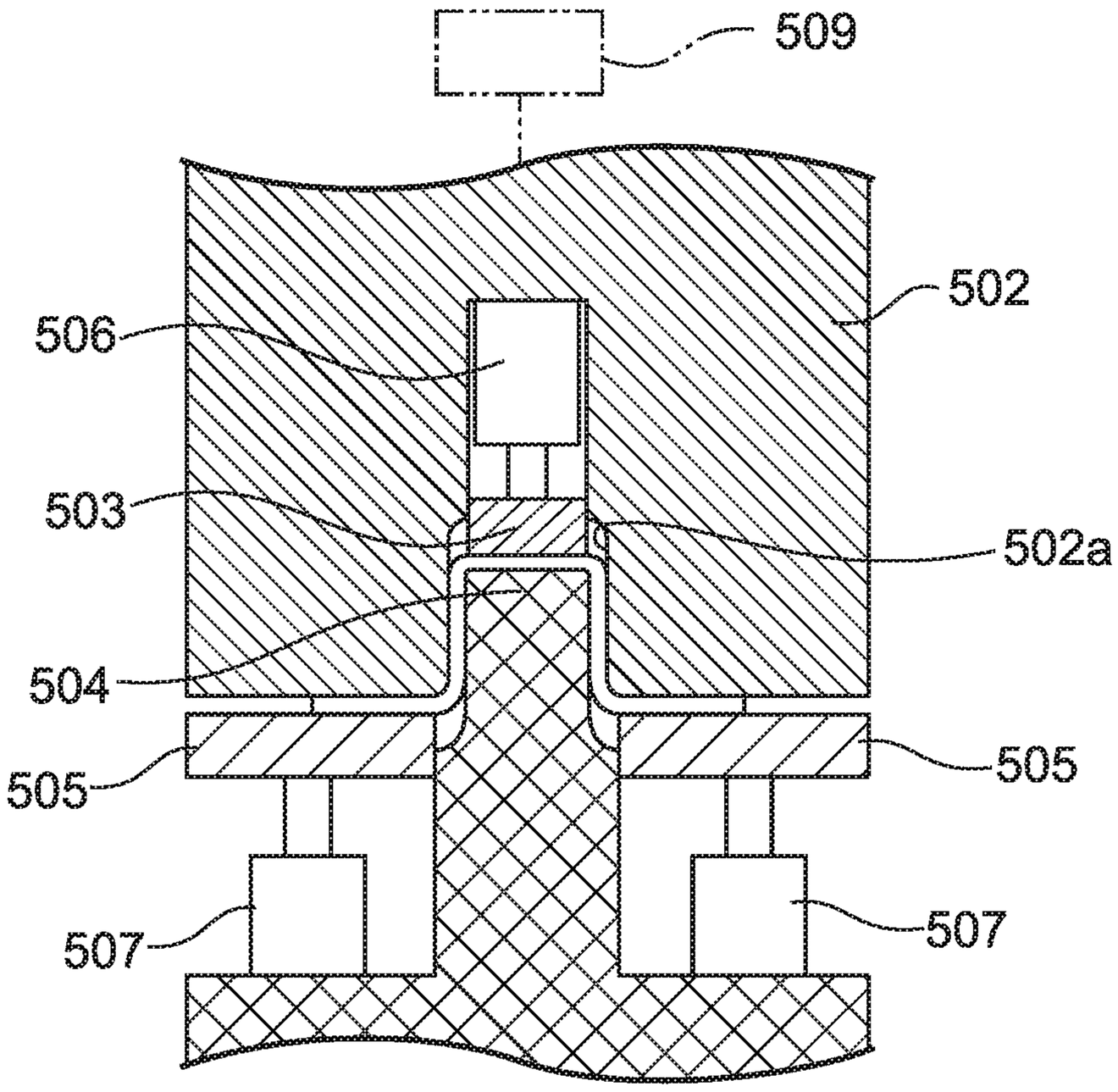

FIG.6D

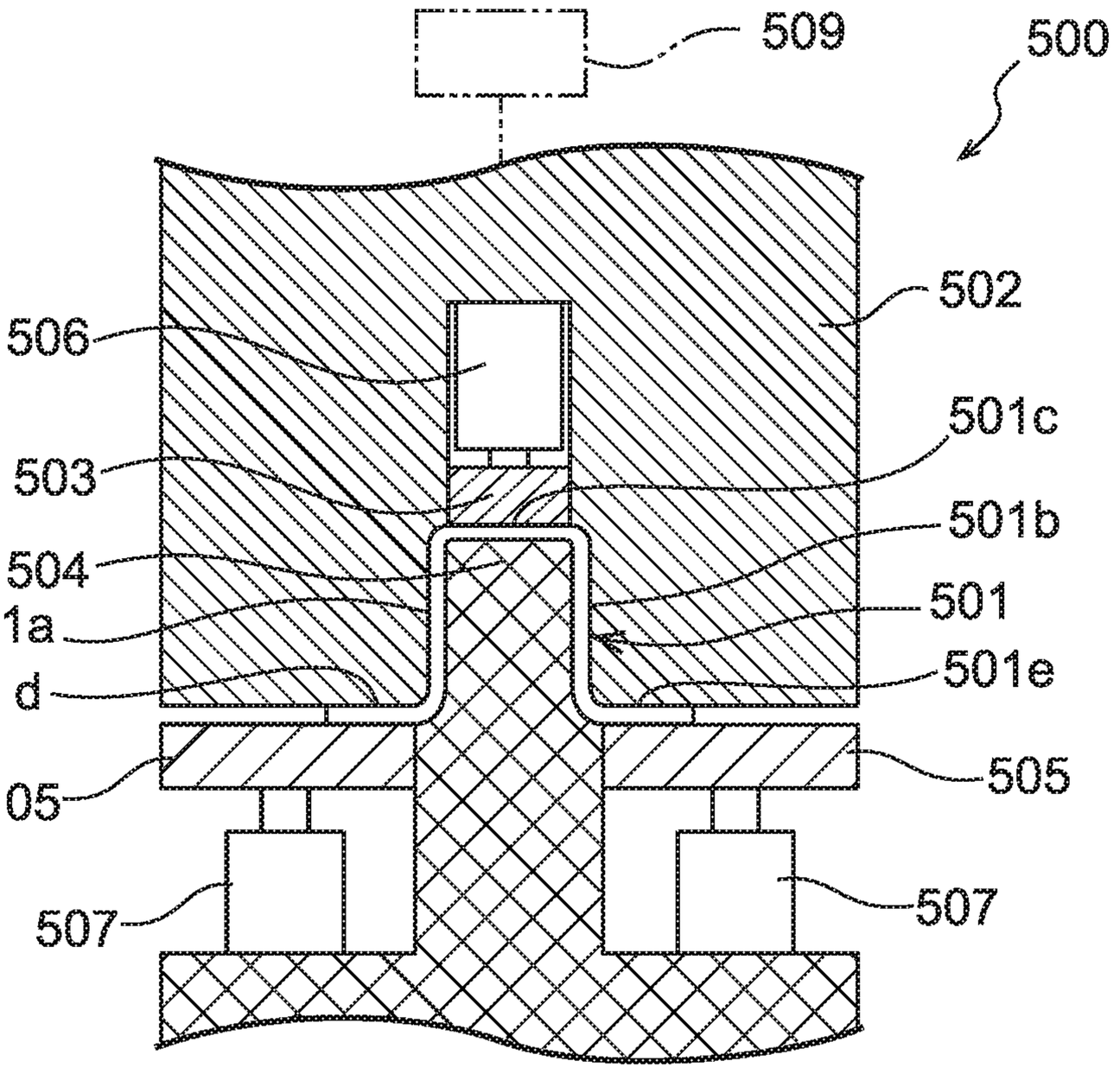

FIG.7

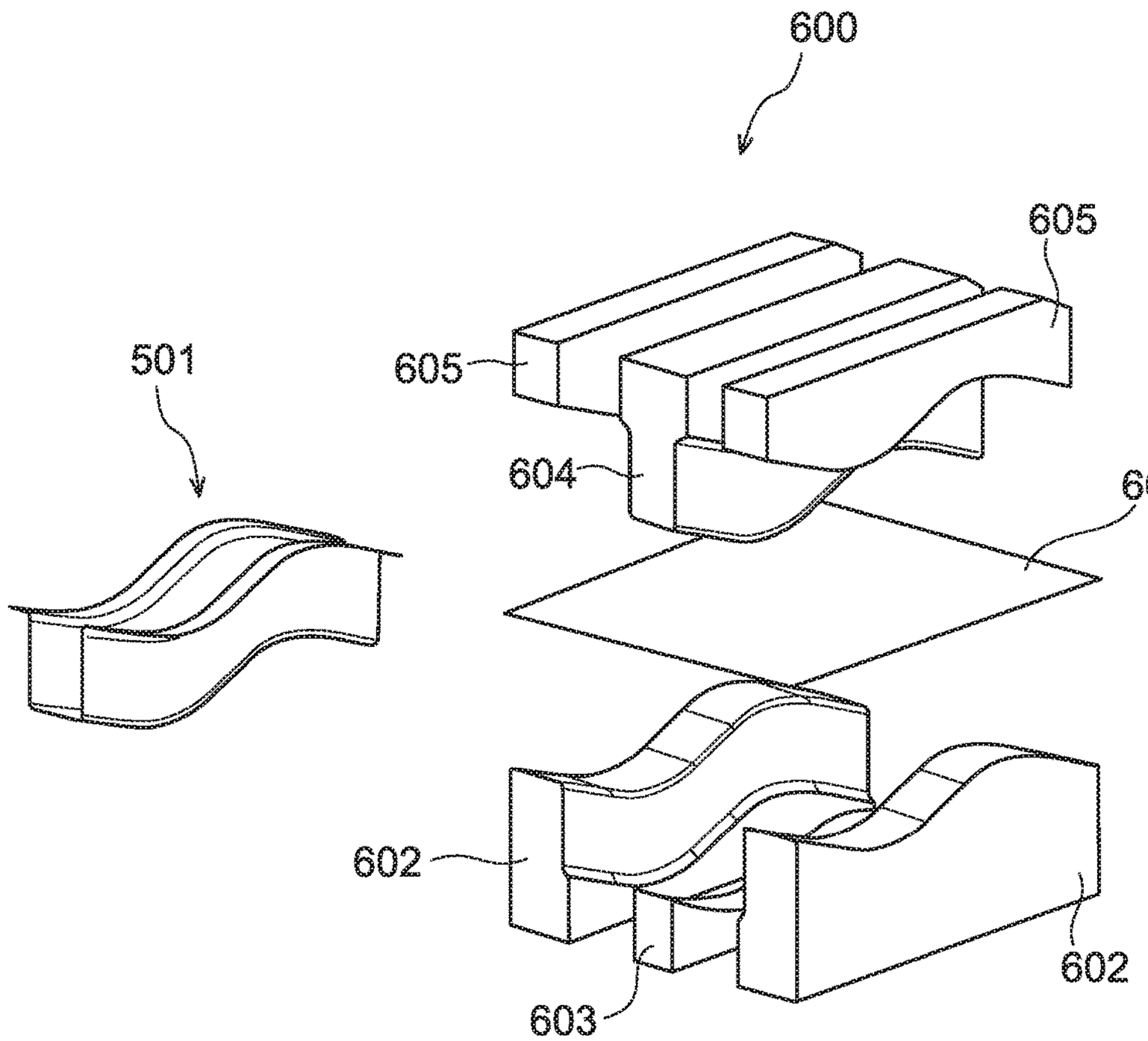

FIG.8A

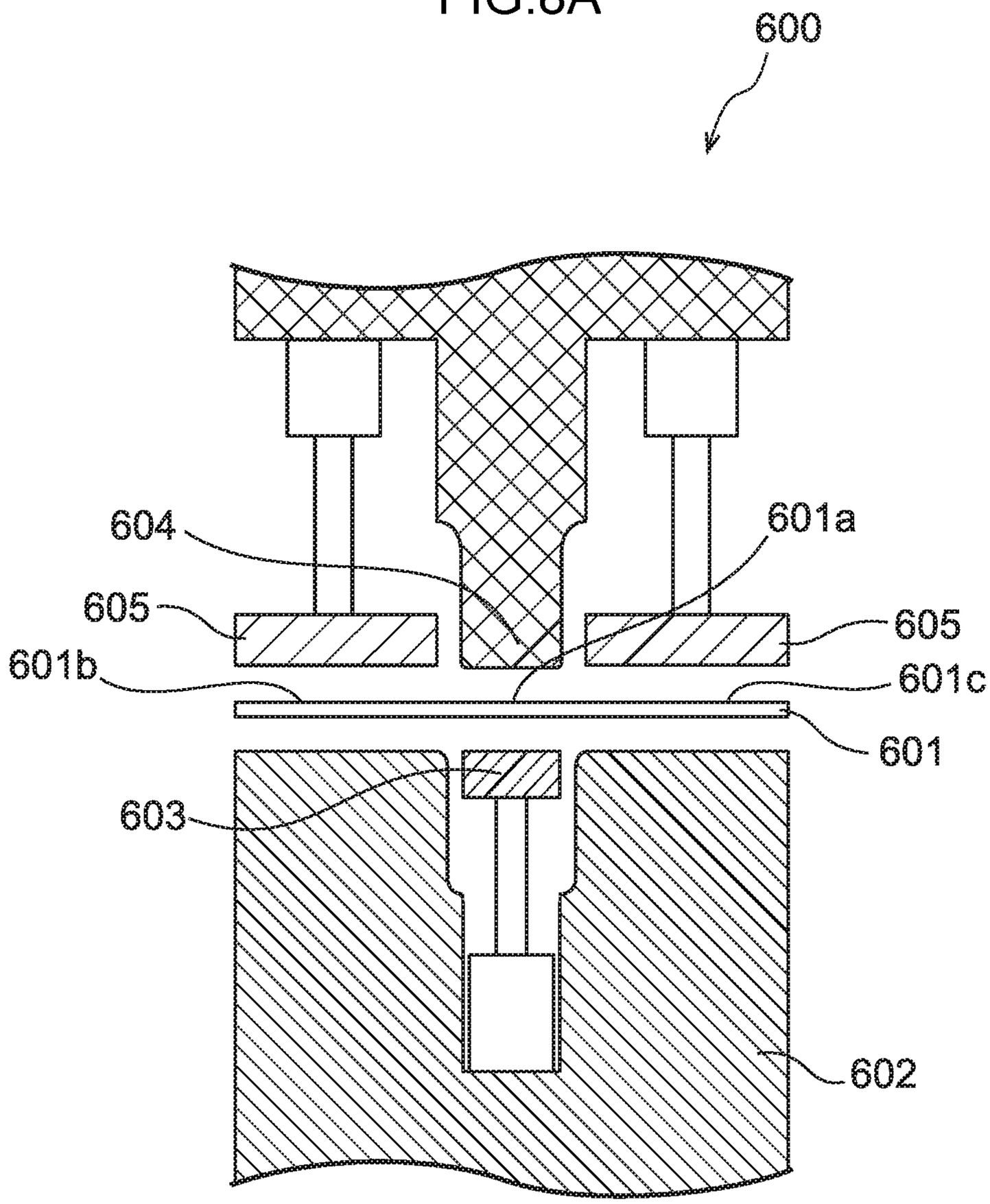

FIG.8B

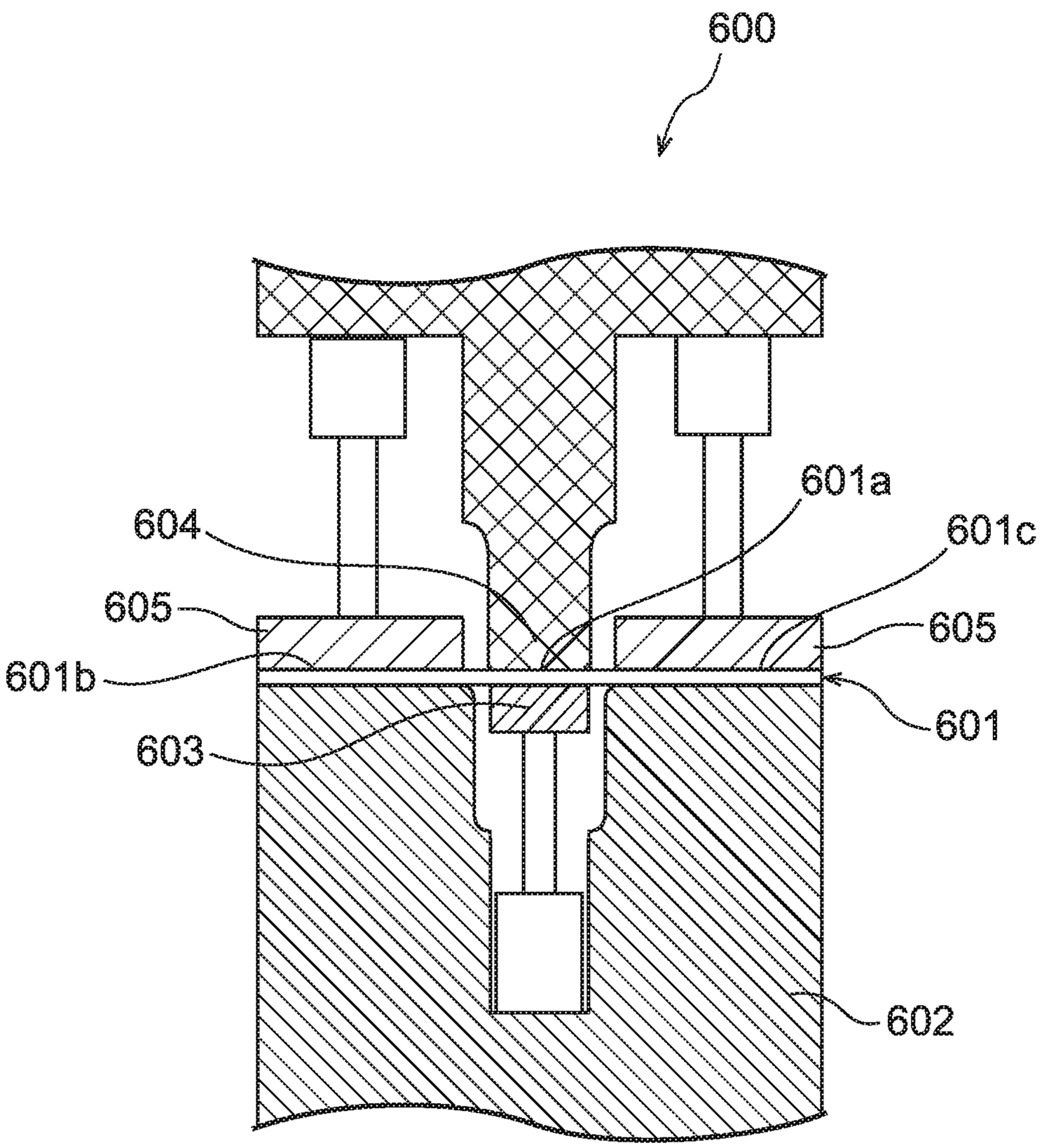

FIG.8C

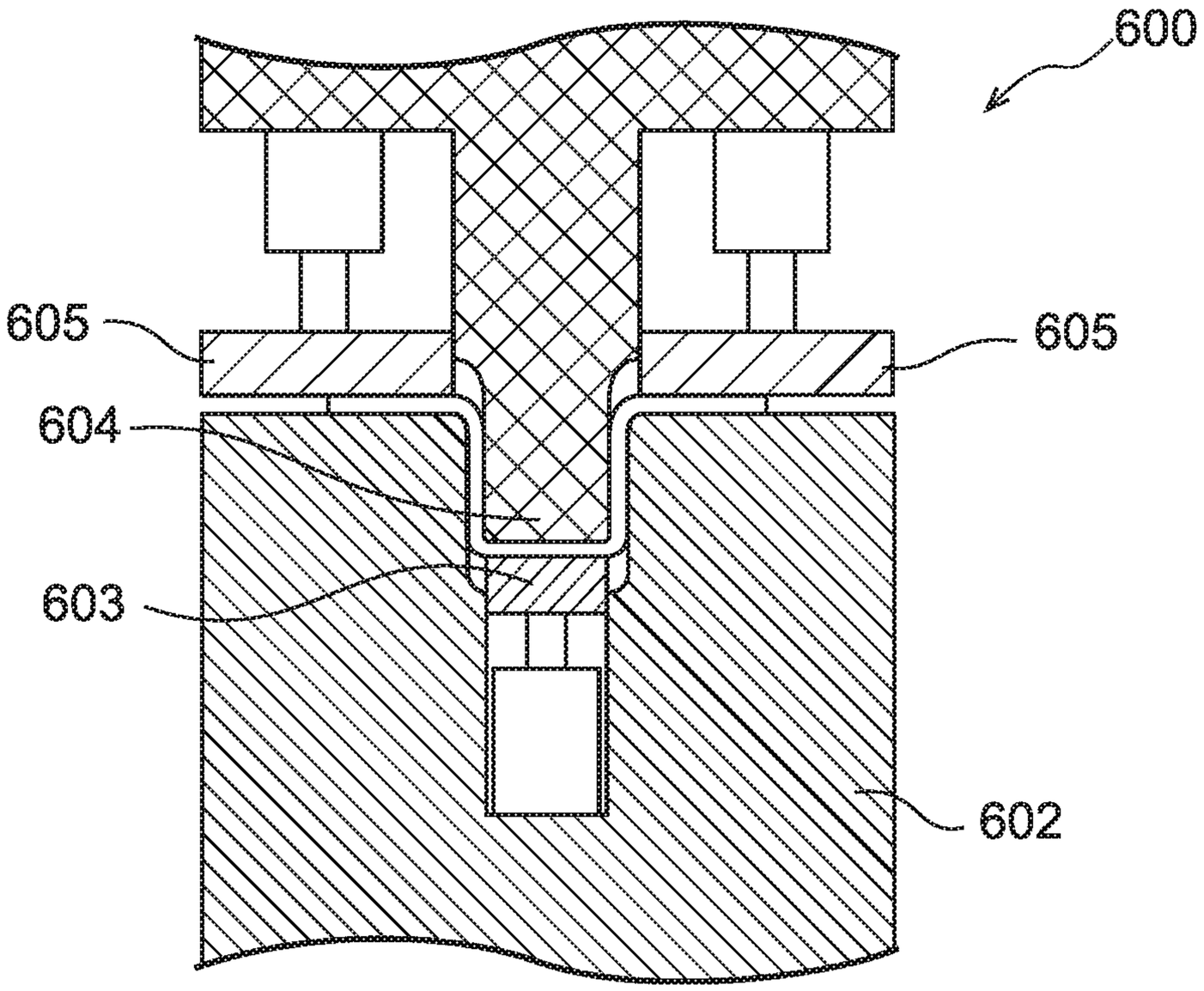

FIG.8D

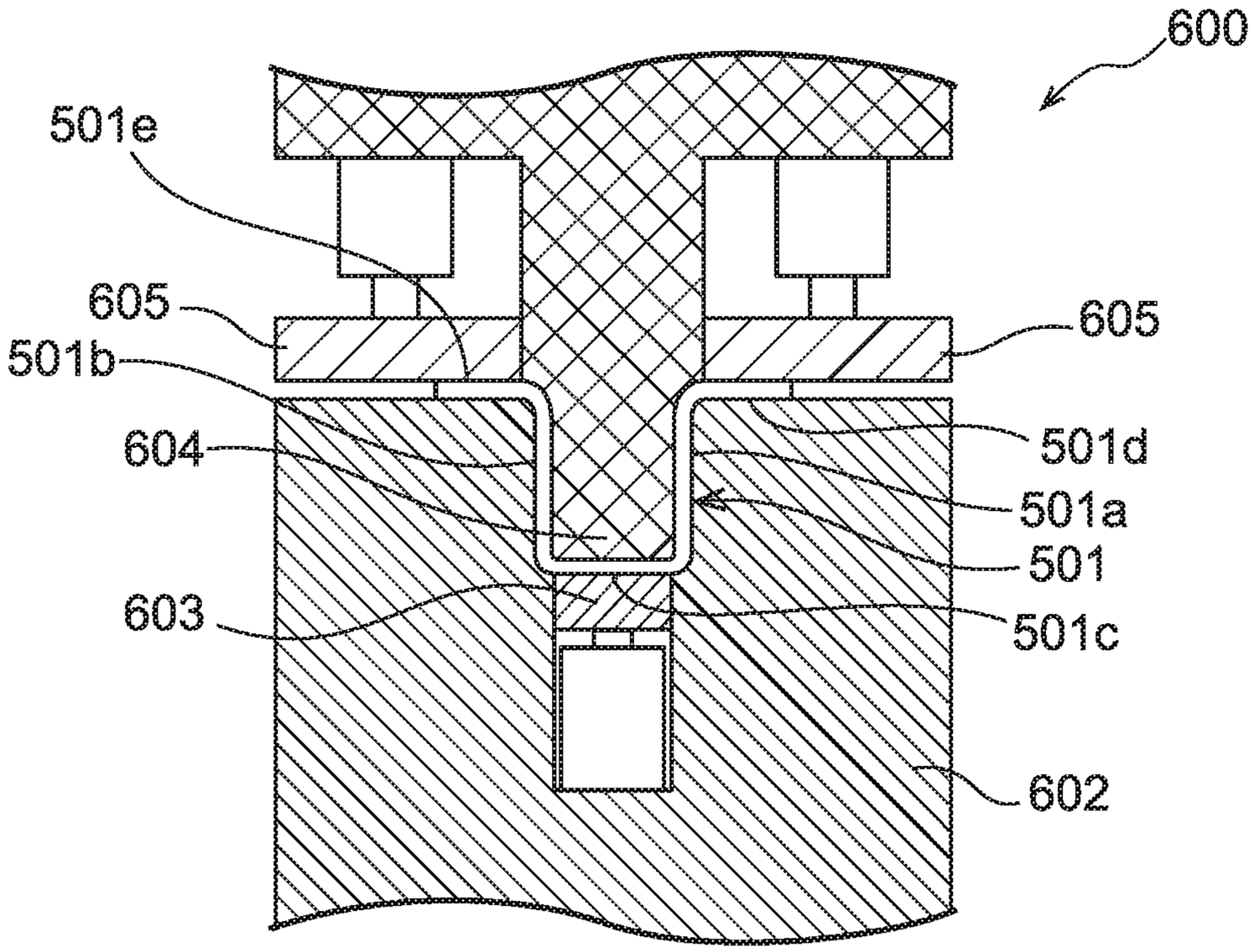

FIG.9A

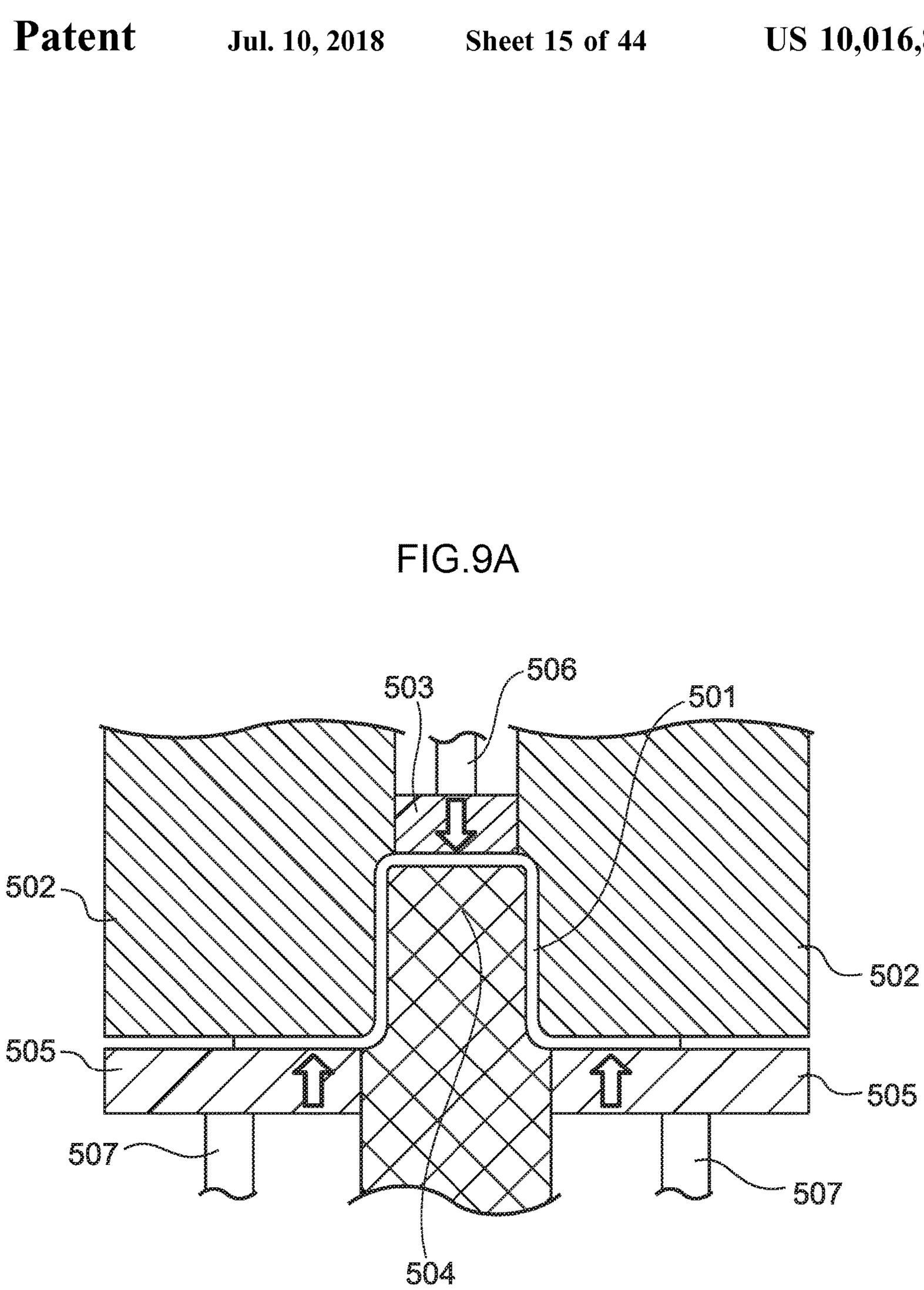

FIG.9B

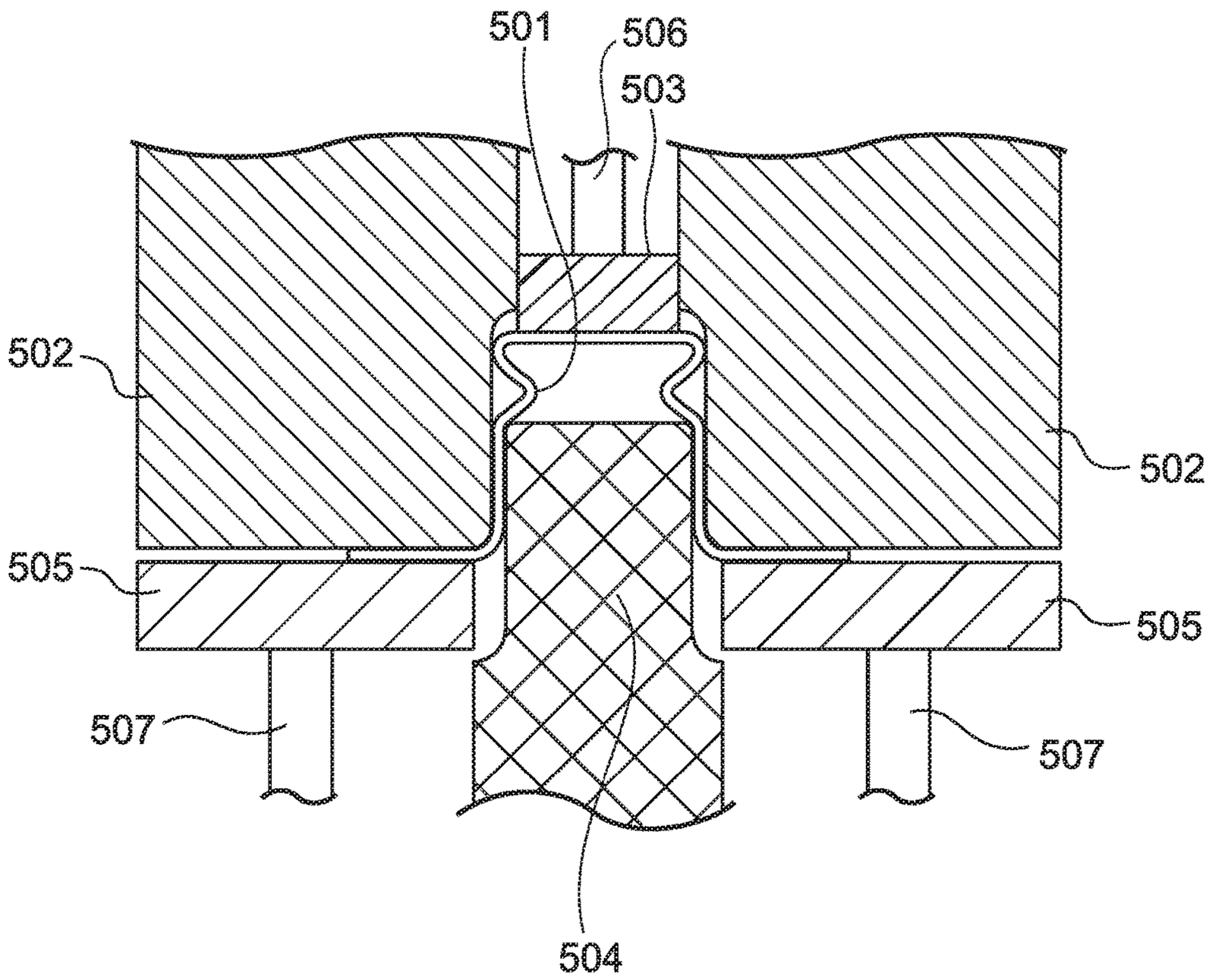

FIG.9C

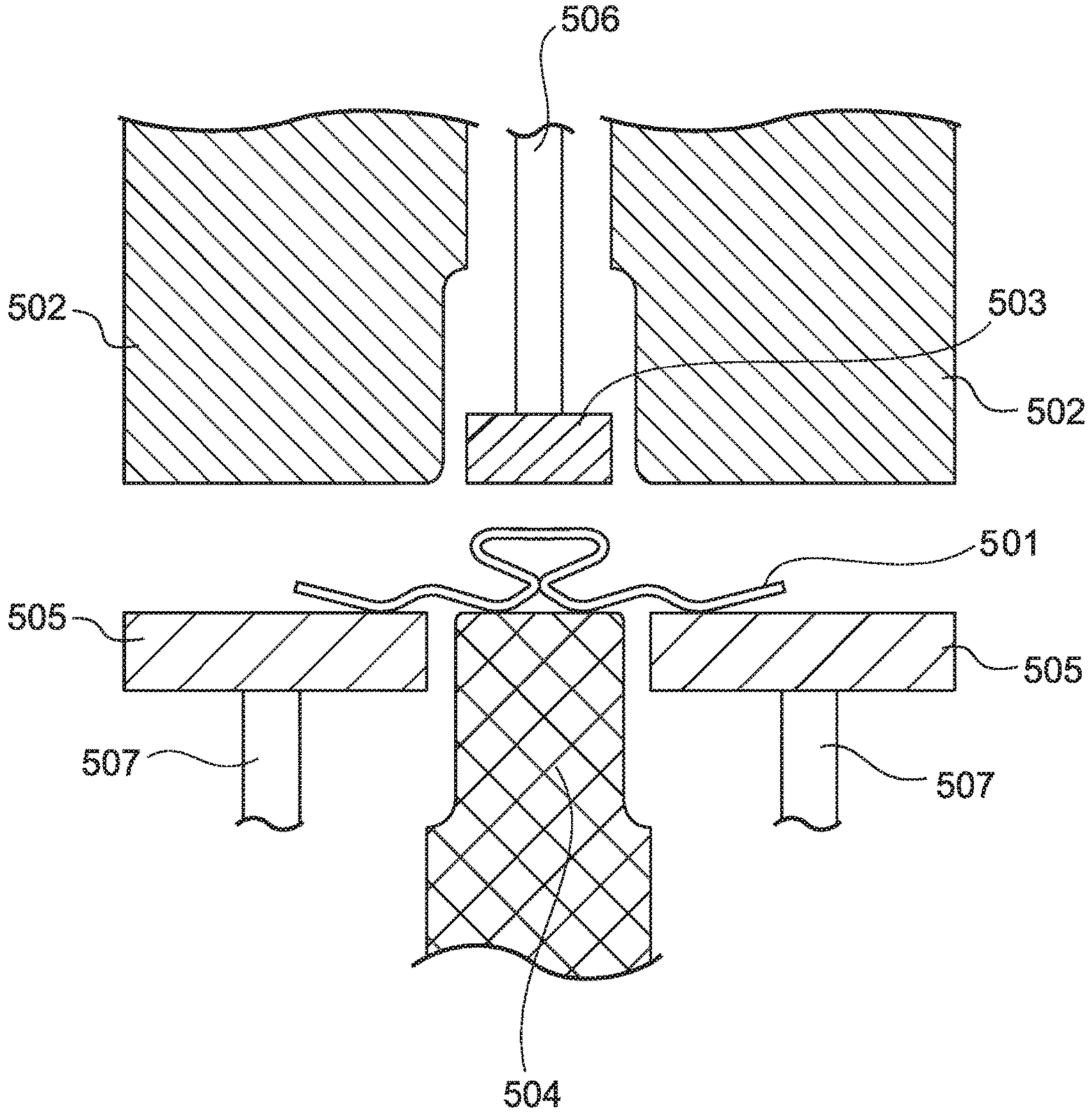

FIG.10A

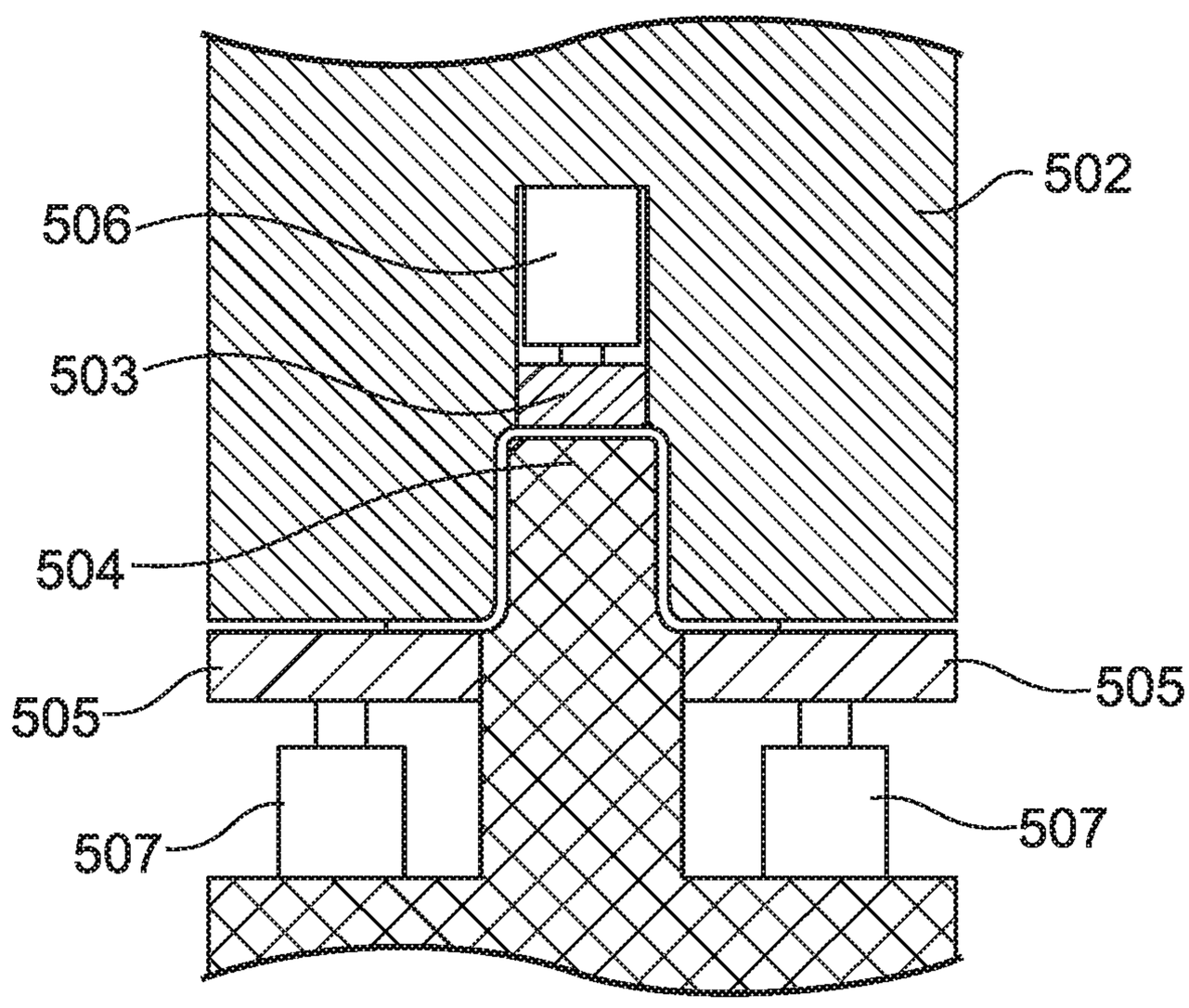

FIG.10B

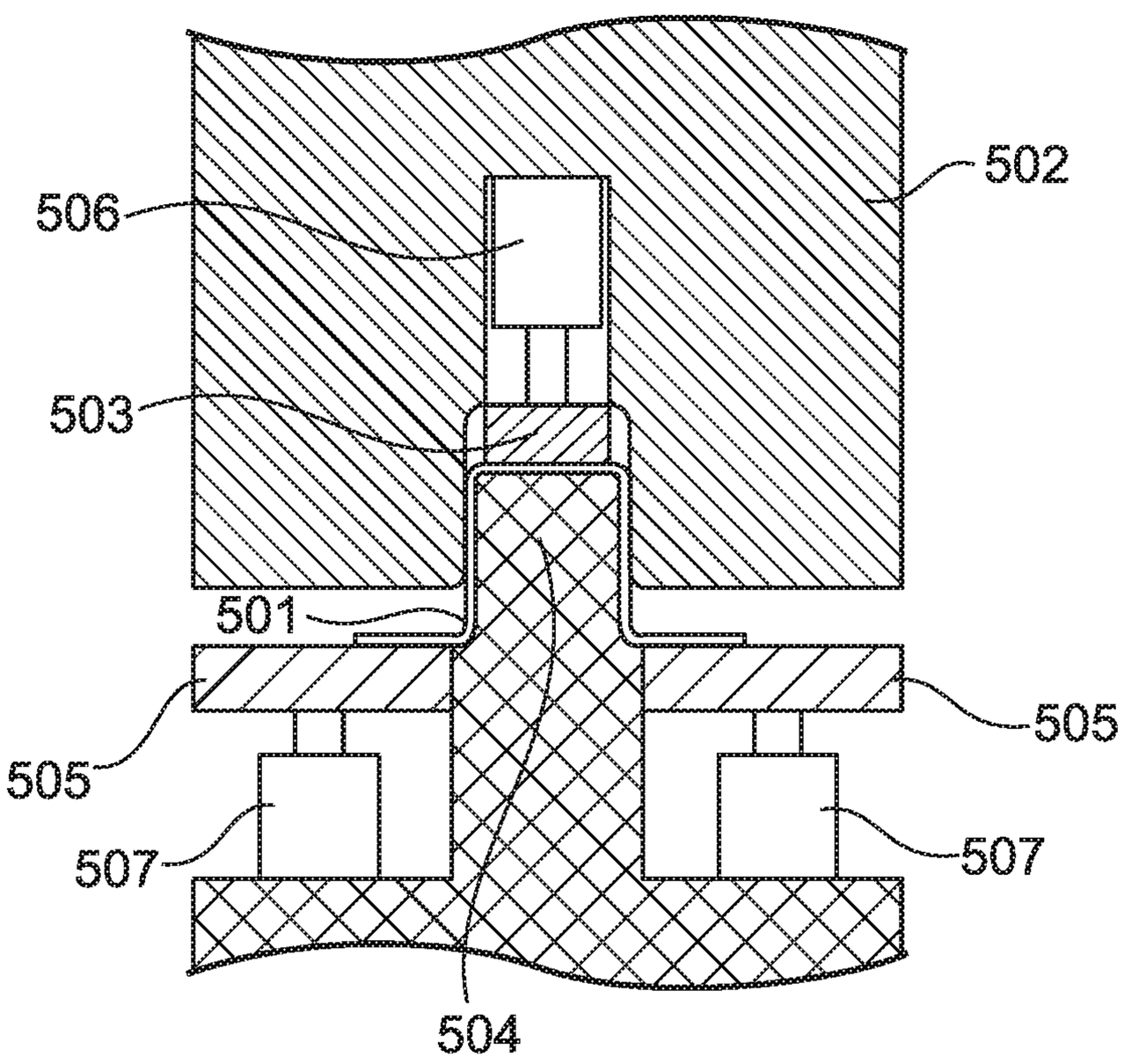

FIG.10C

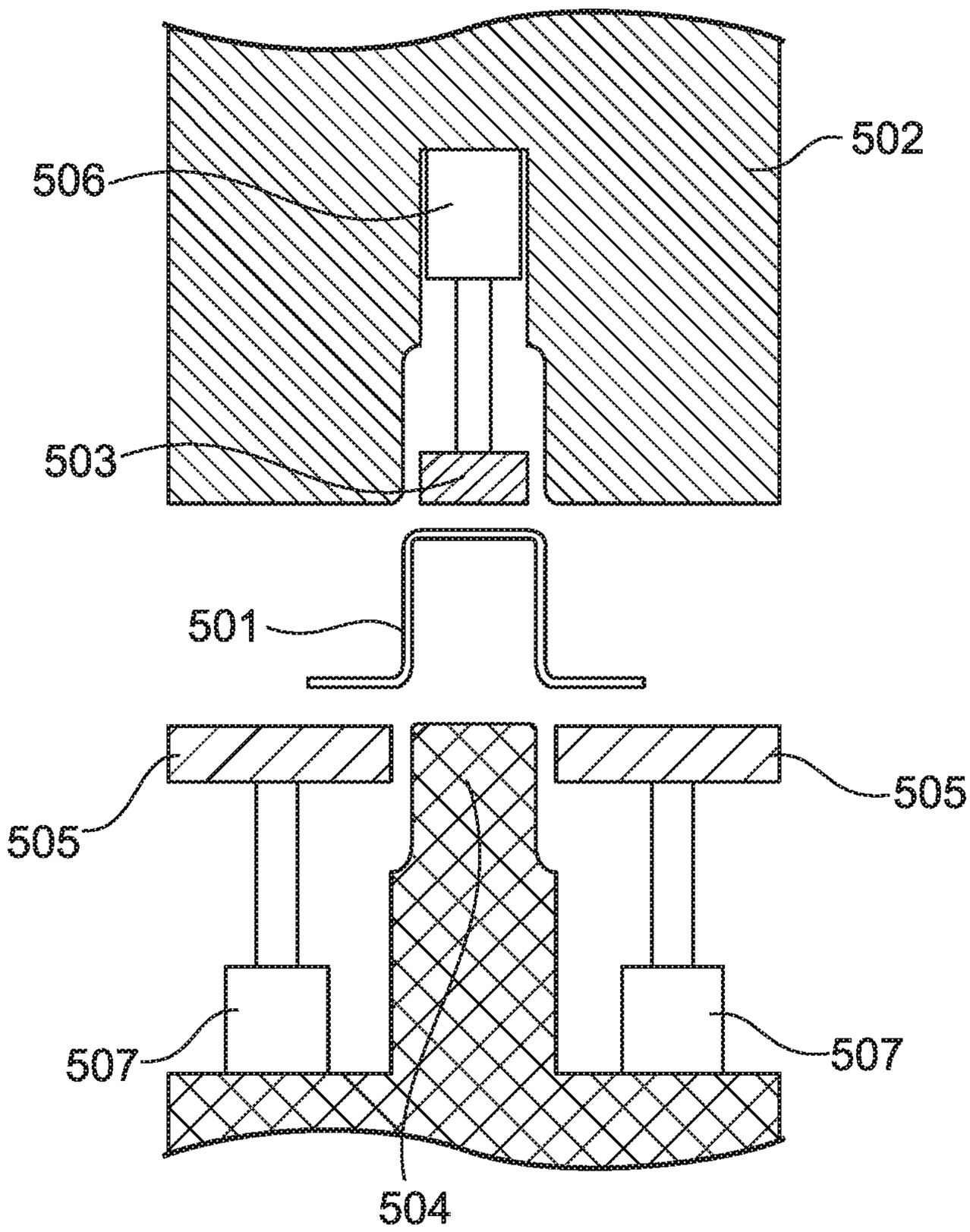

FIG.11A

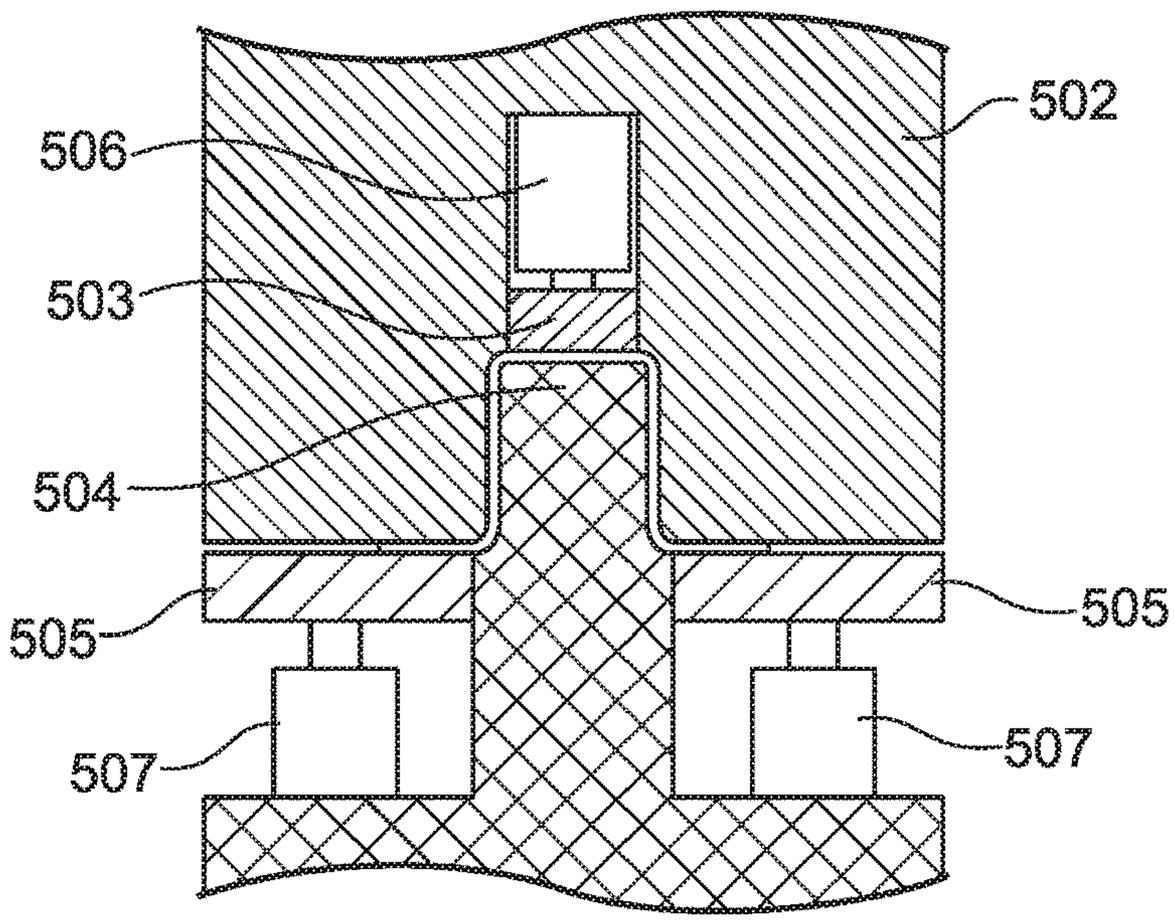

FIG.11B

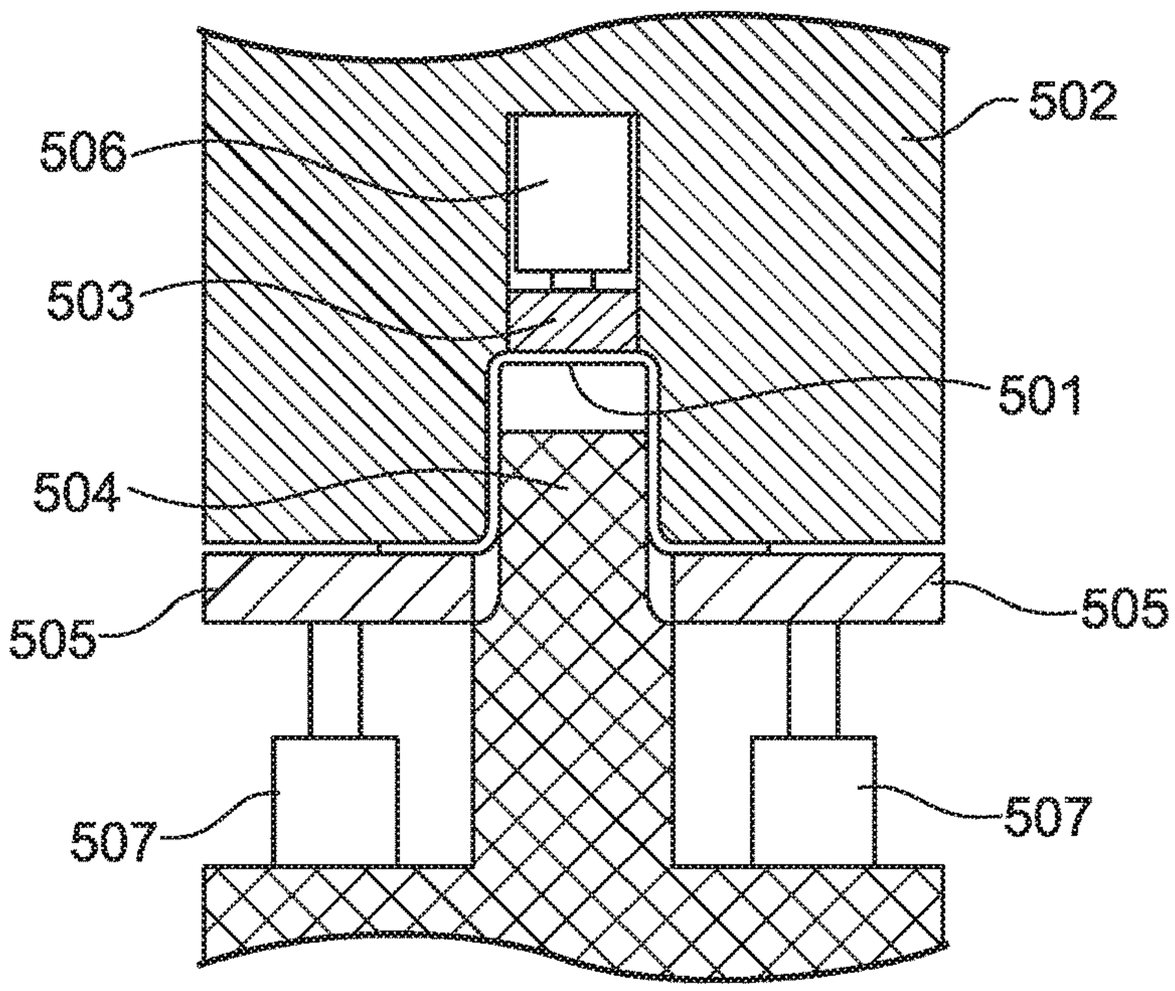

FIG.11C

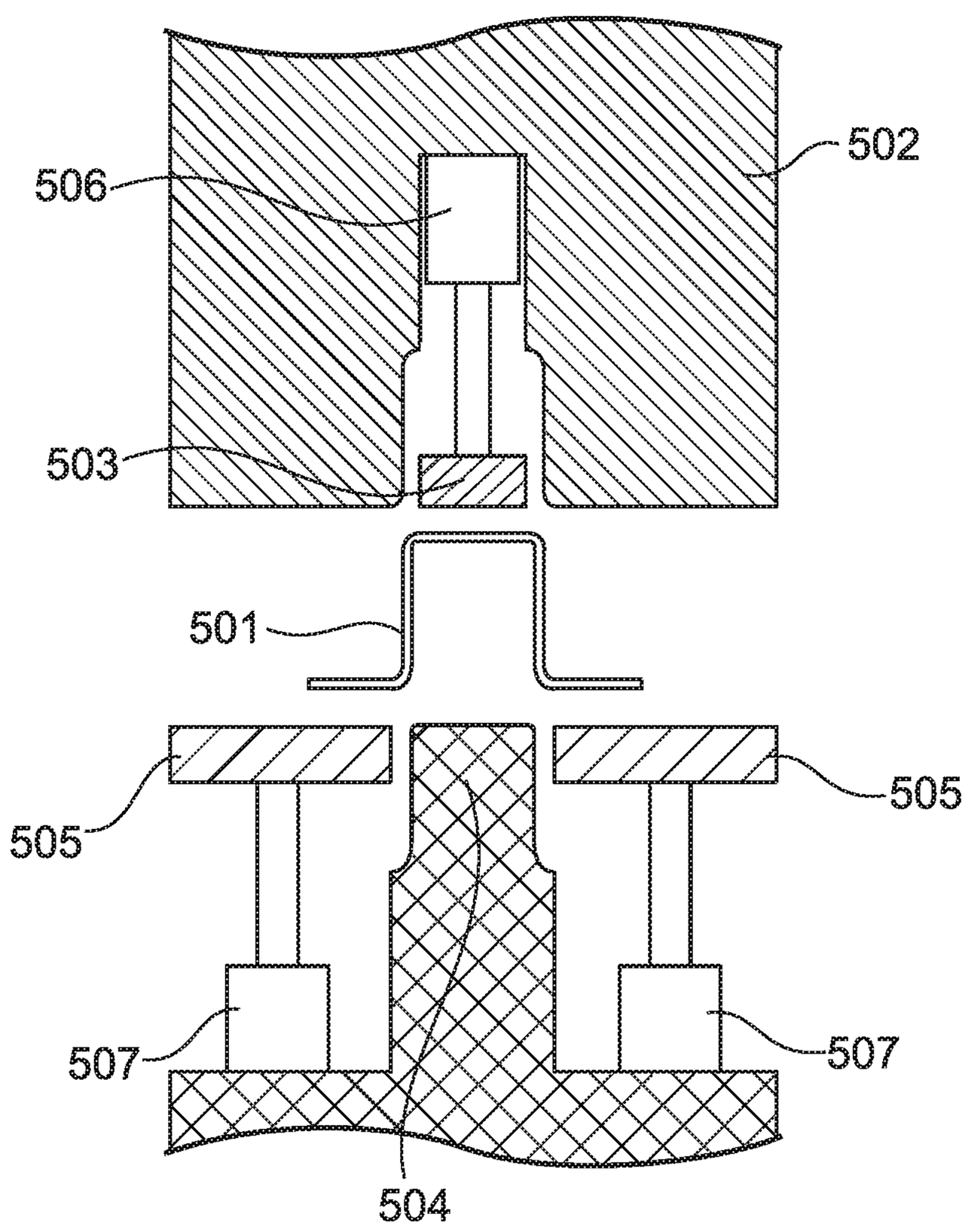

FIG.12A

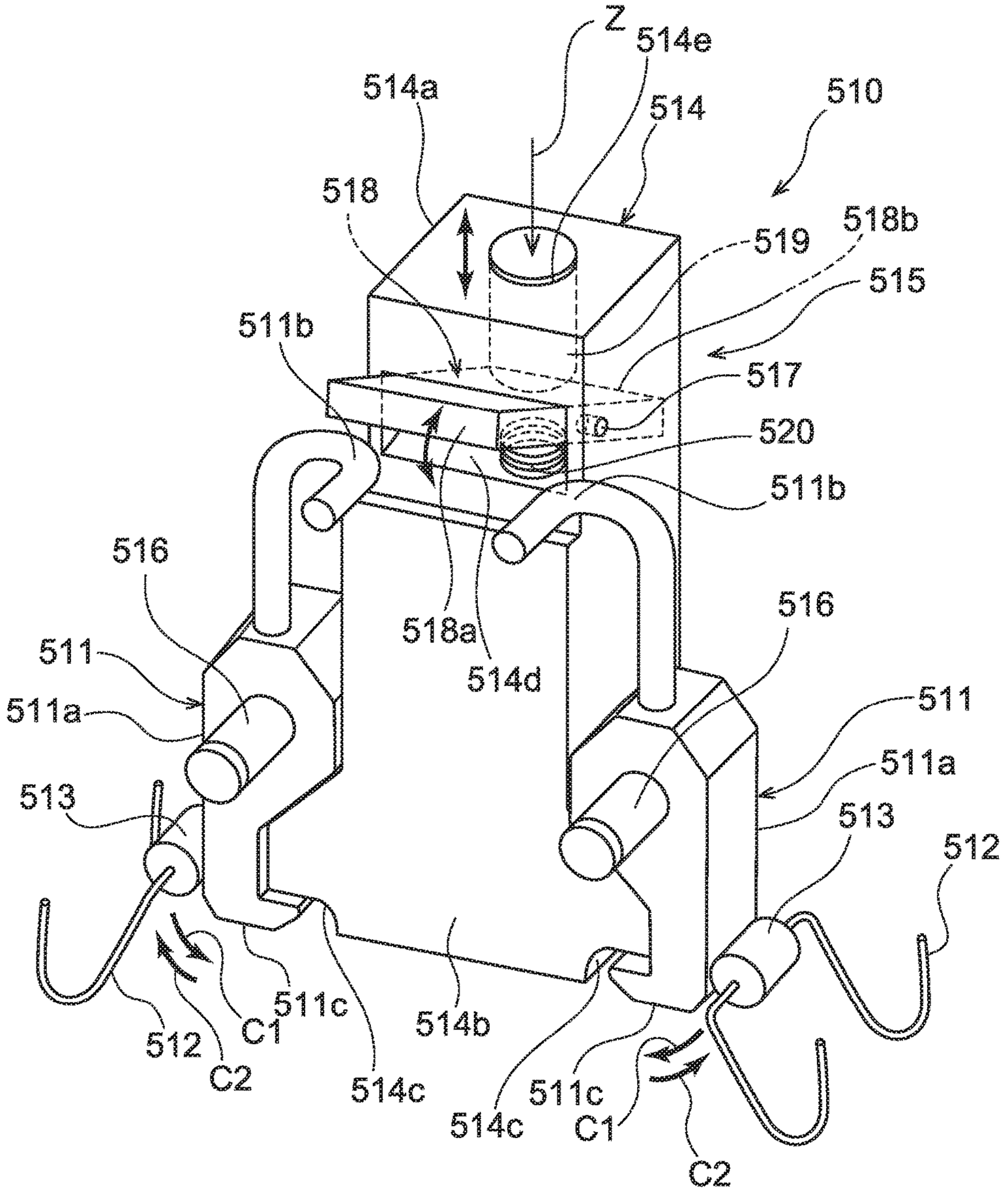
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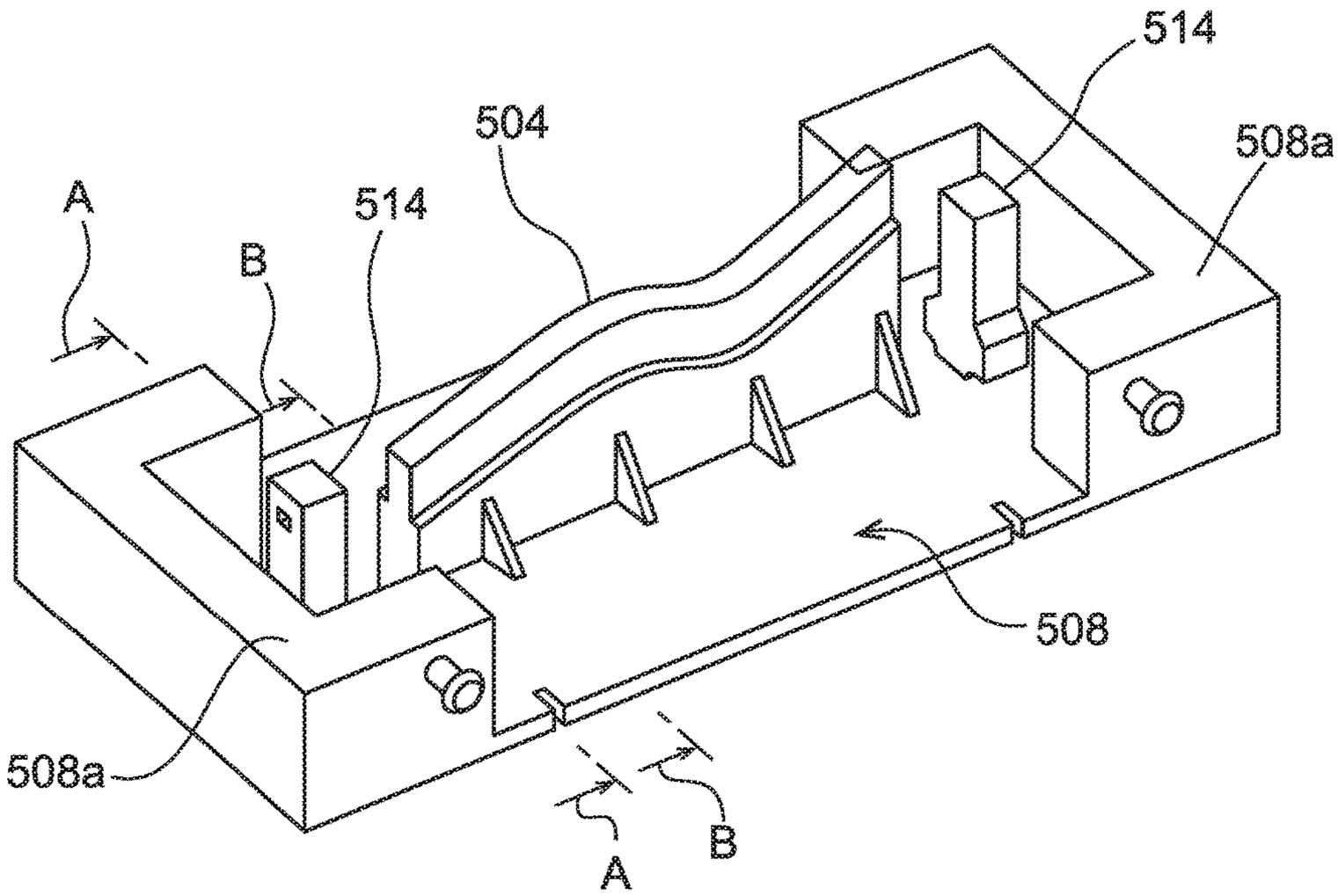
FIG.12B



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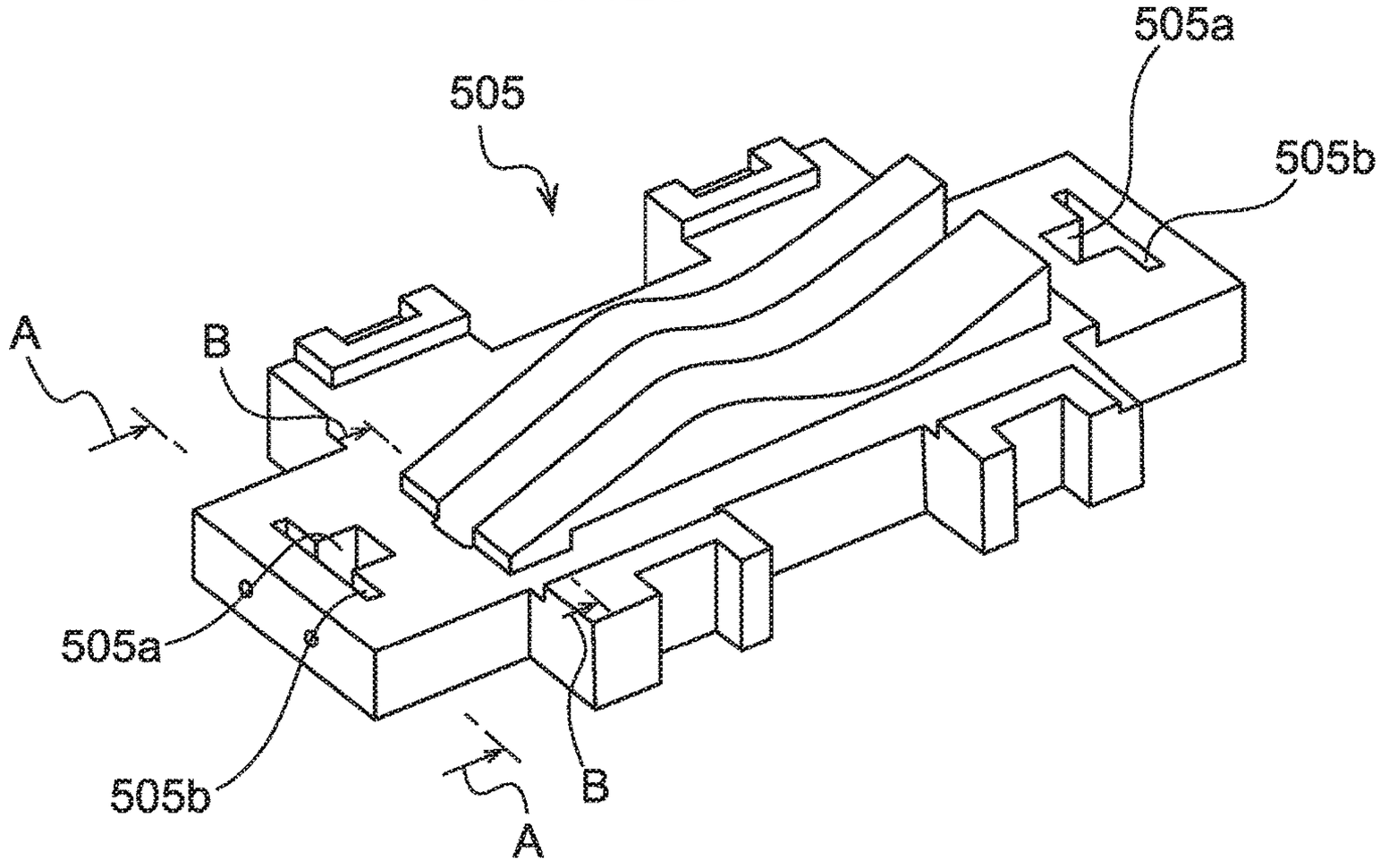

FIG.12D

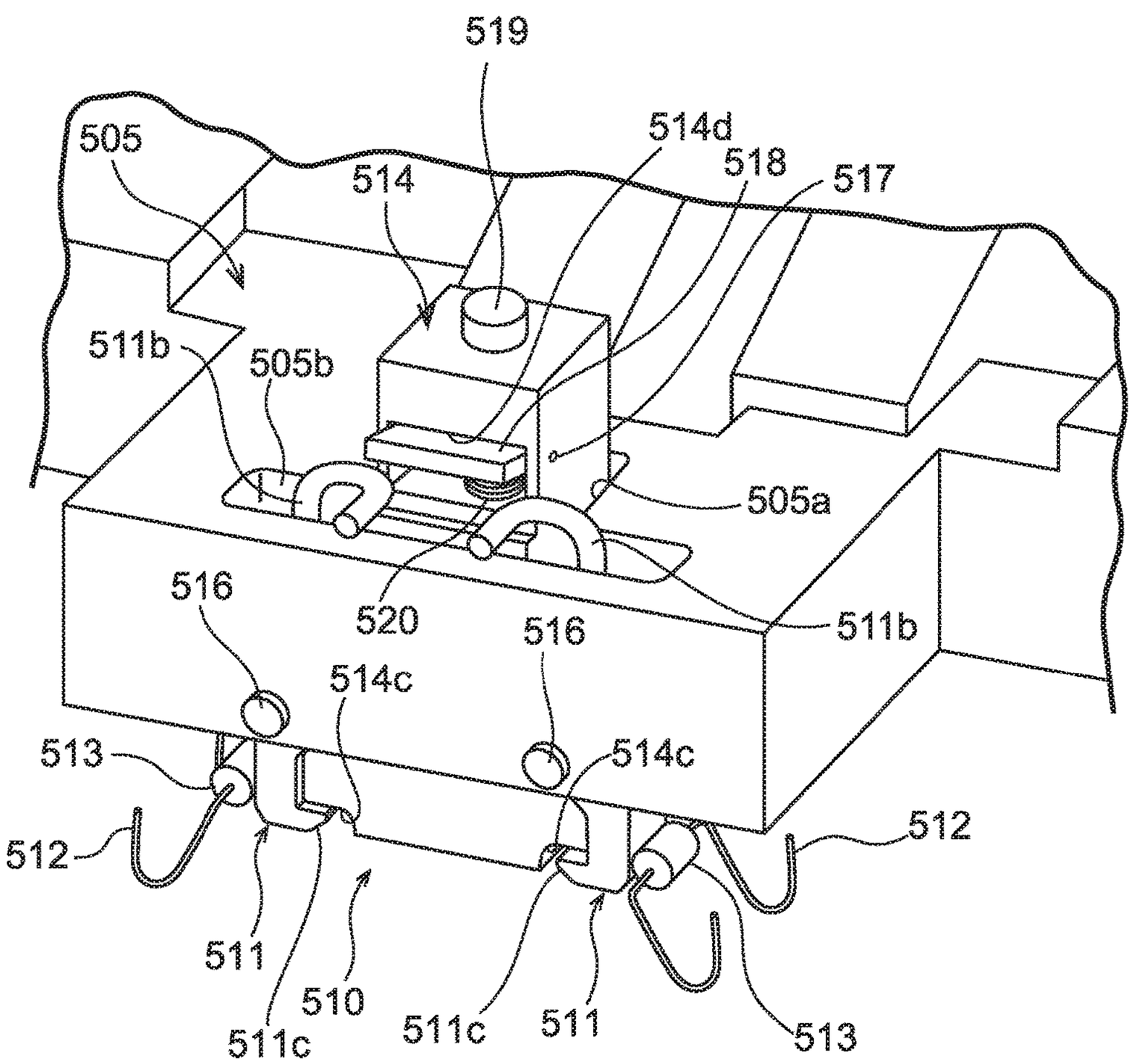
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FIG.12E

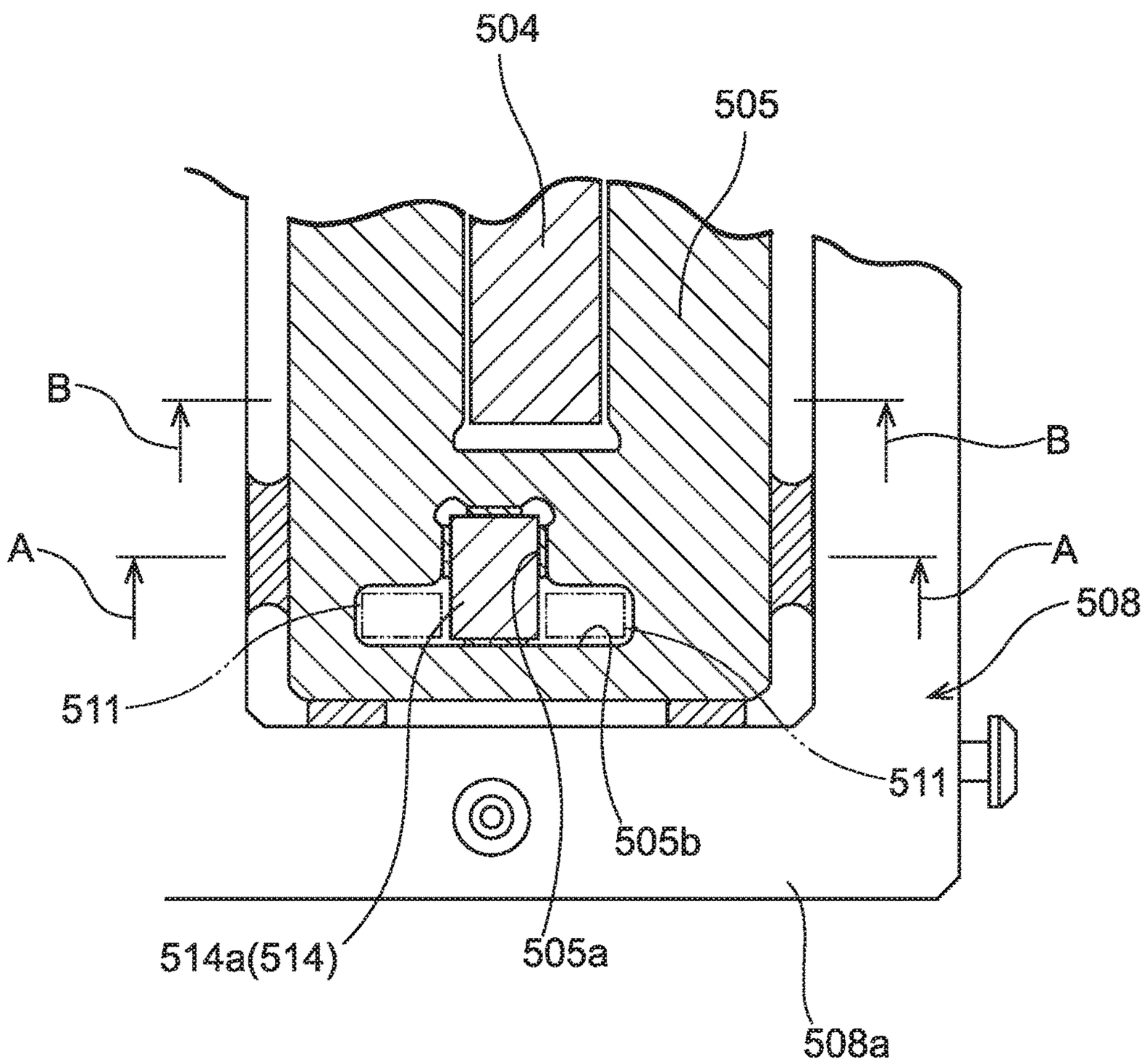
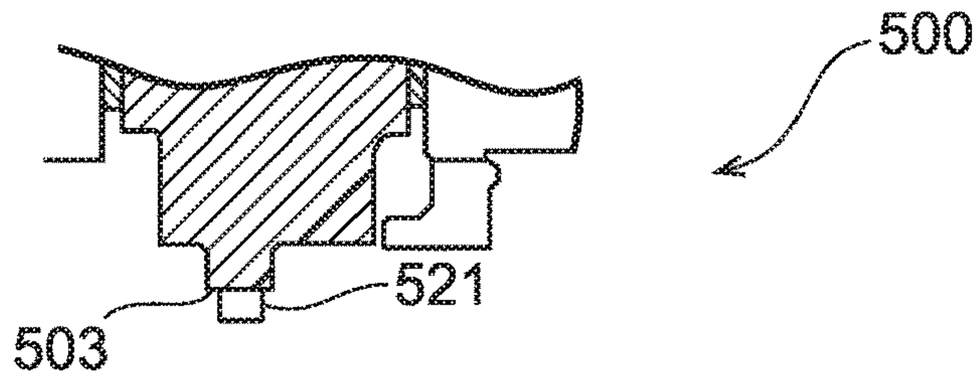


FIG.13A



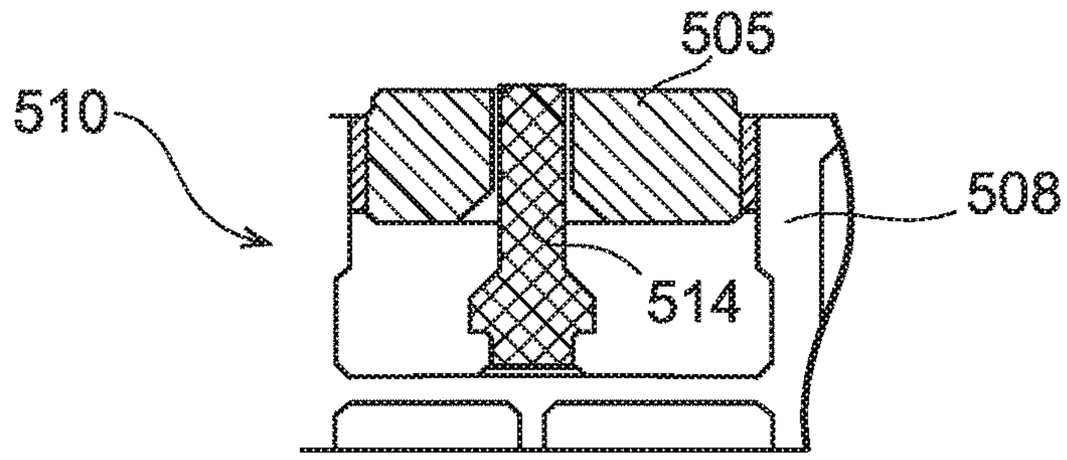


FIG.13B

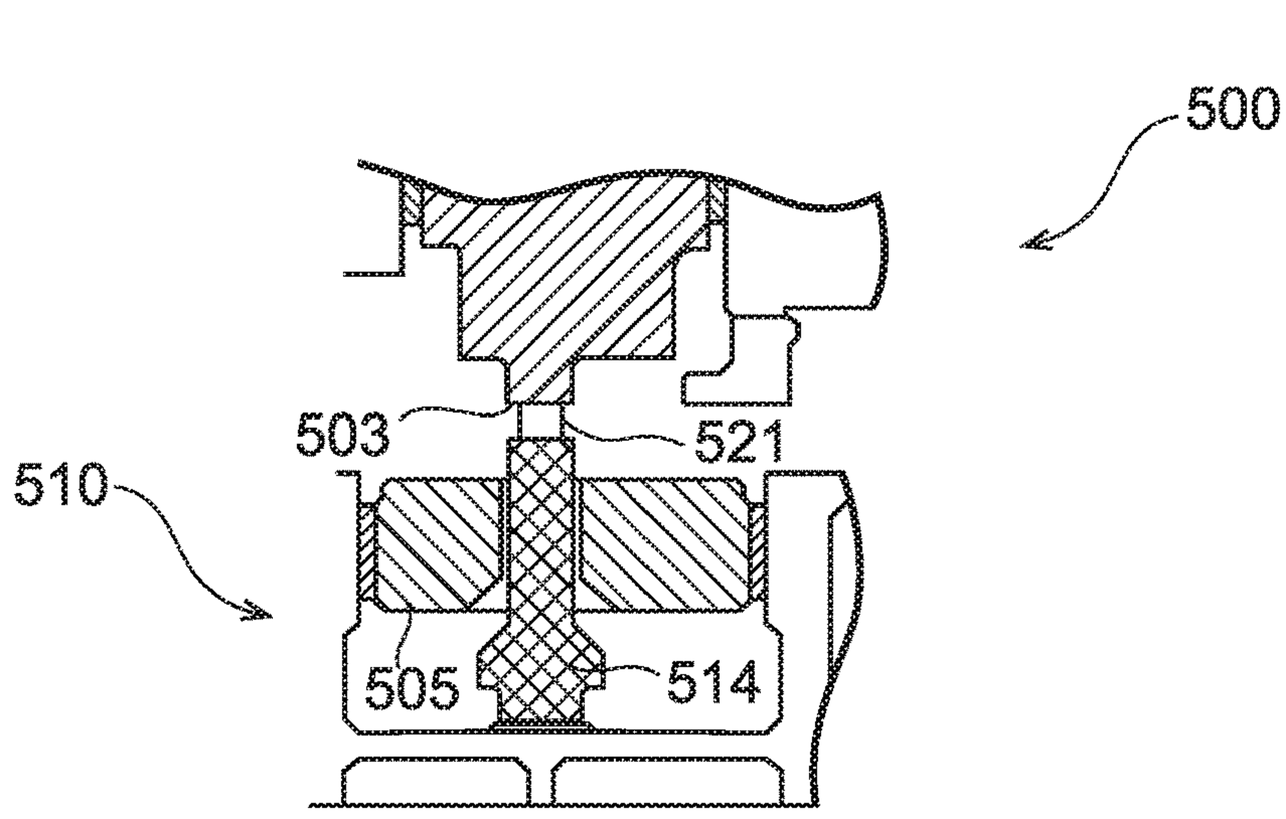


FIG.13C

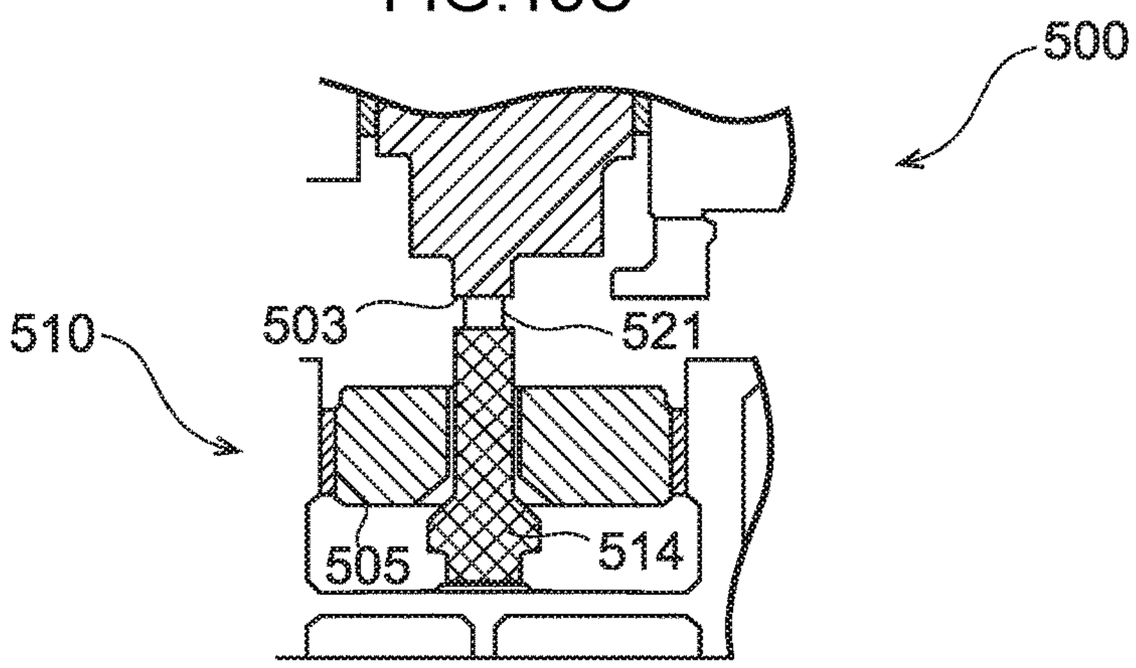


FIG.13D

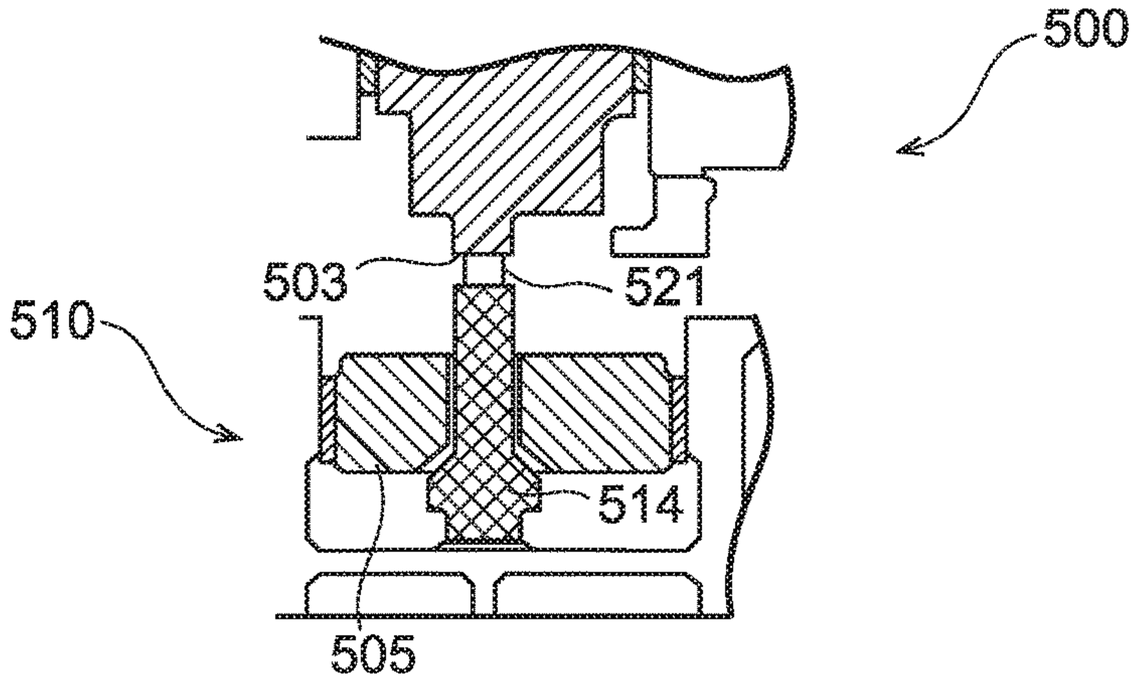


FIG.13E

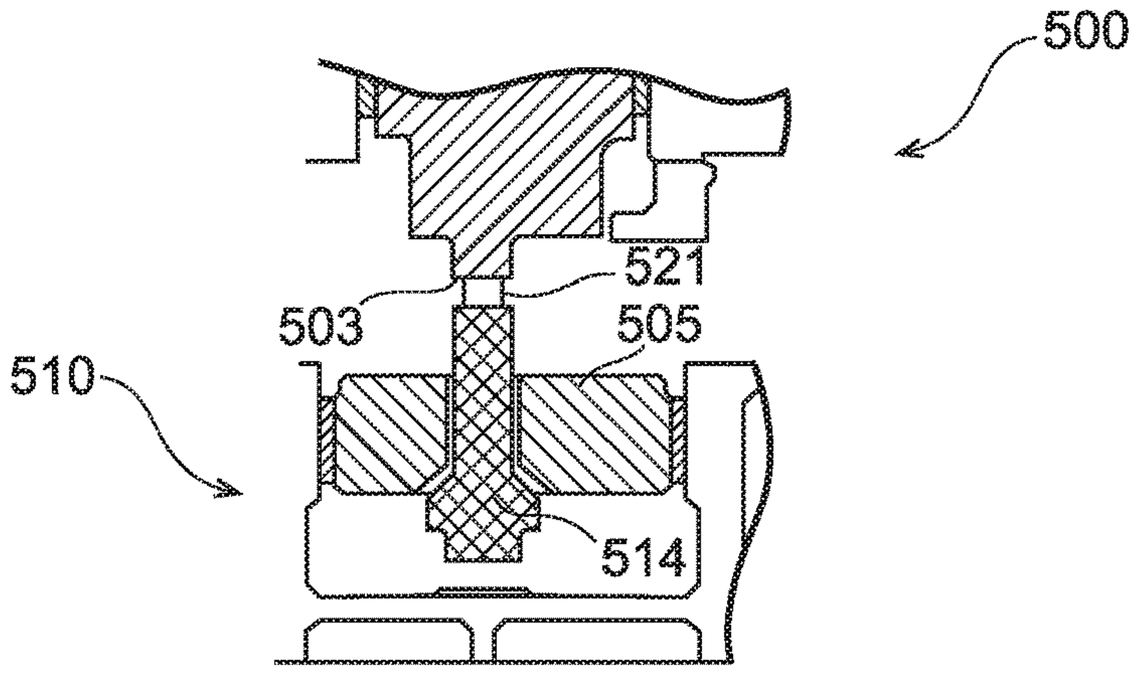


FIG.13F

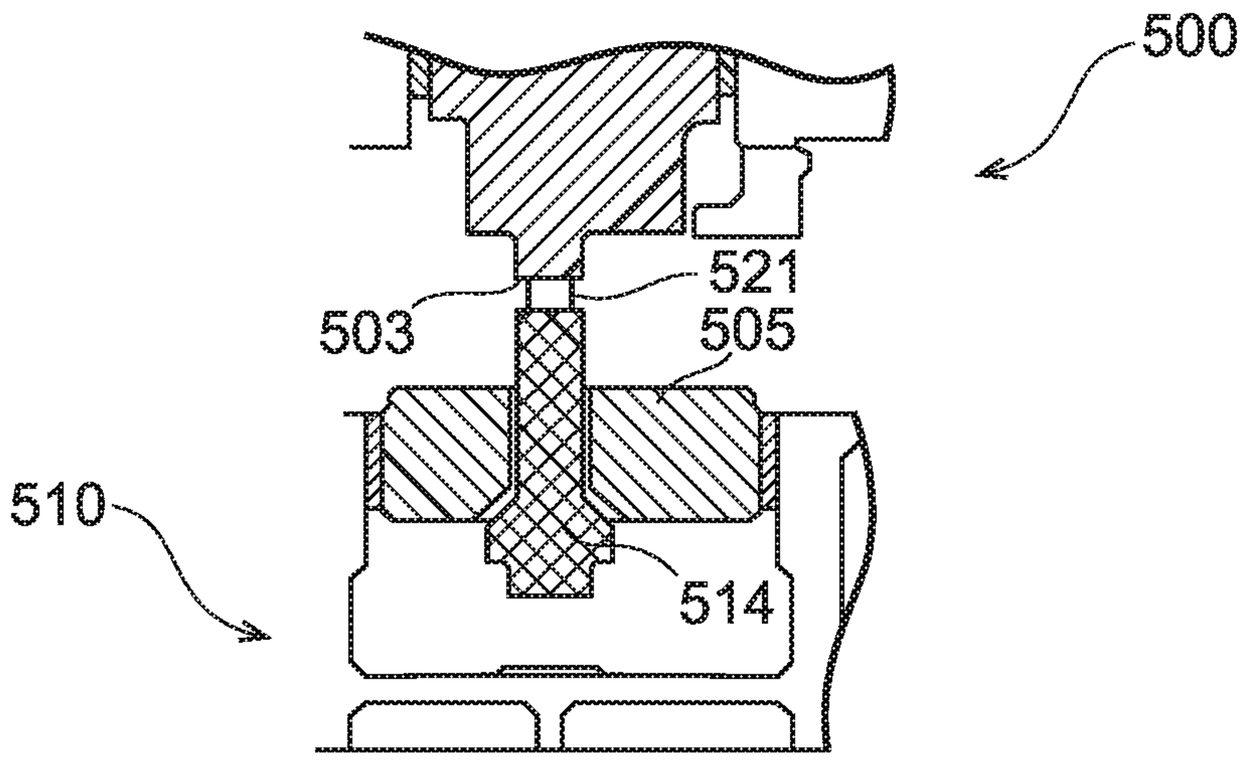
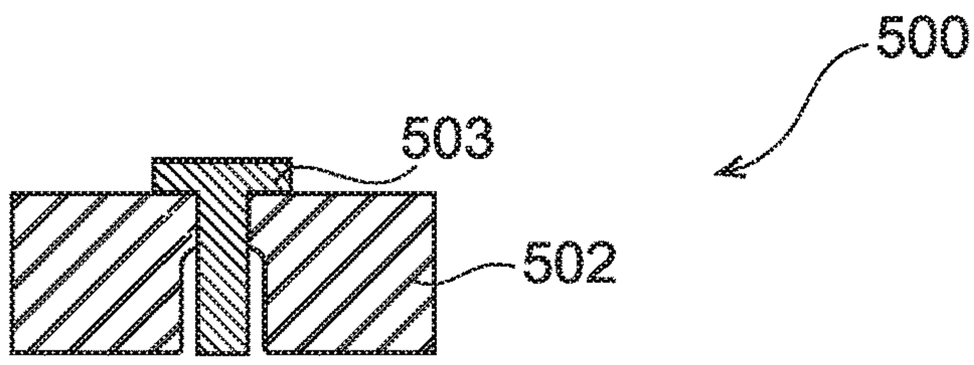


FIG.13G

FIG.14A



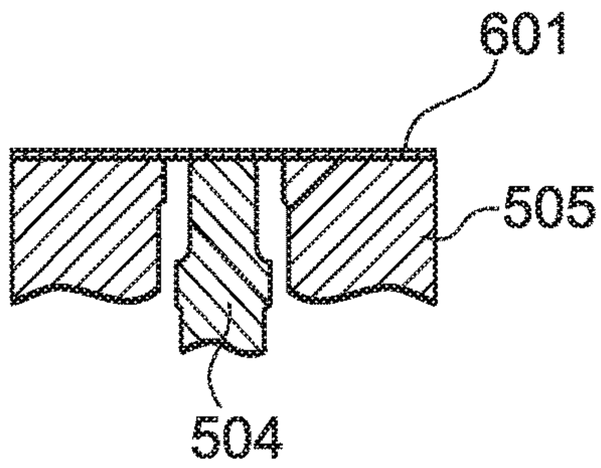


FIG.14B

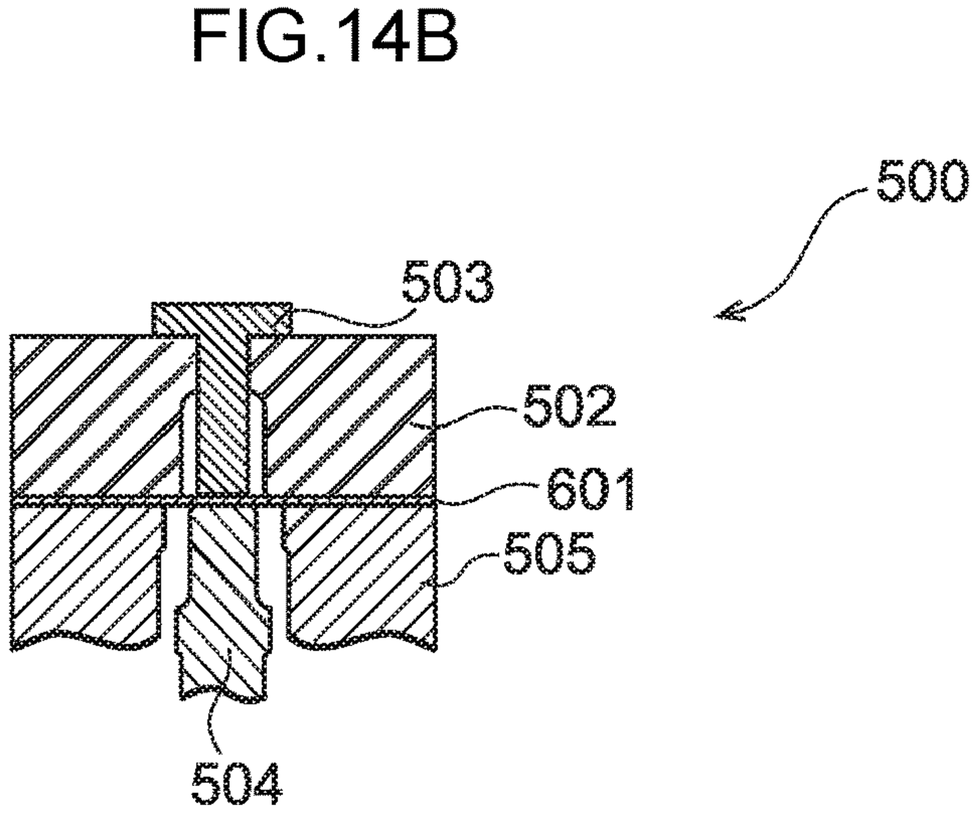


FIG.14C

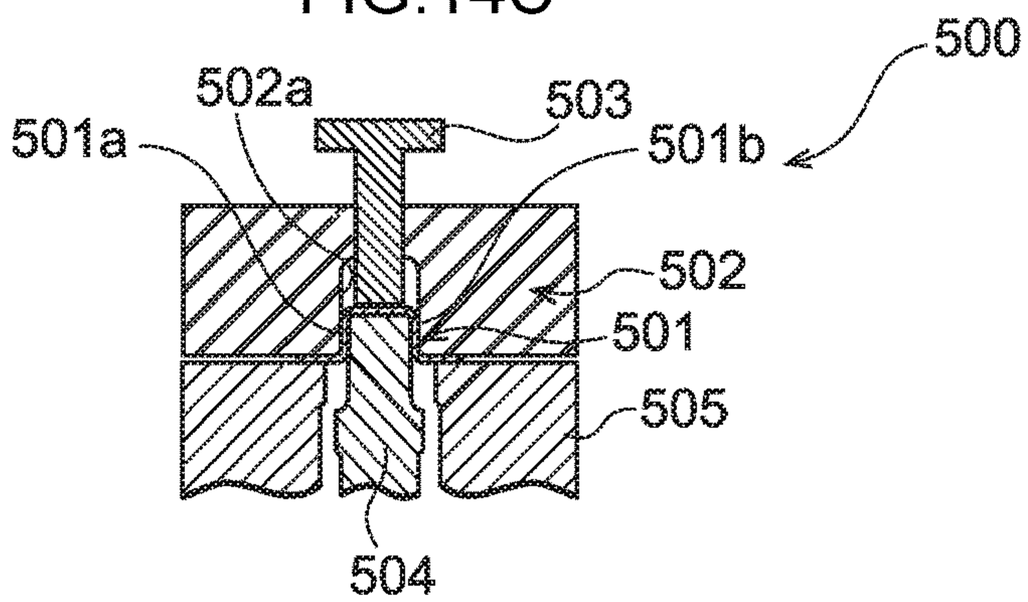


FIG.14D

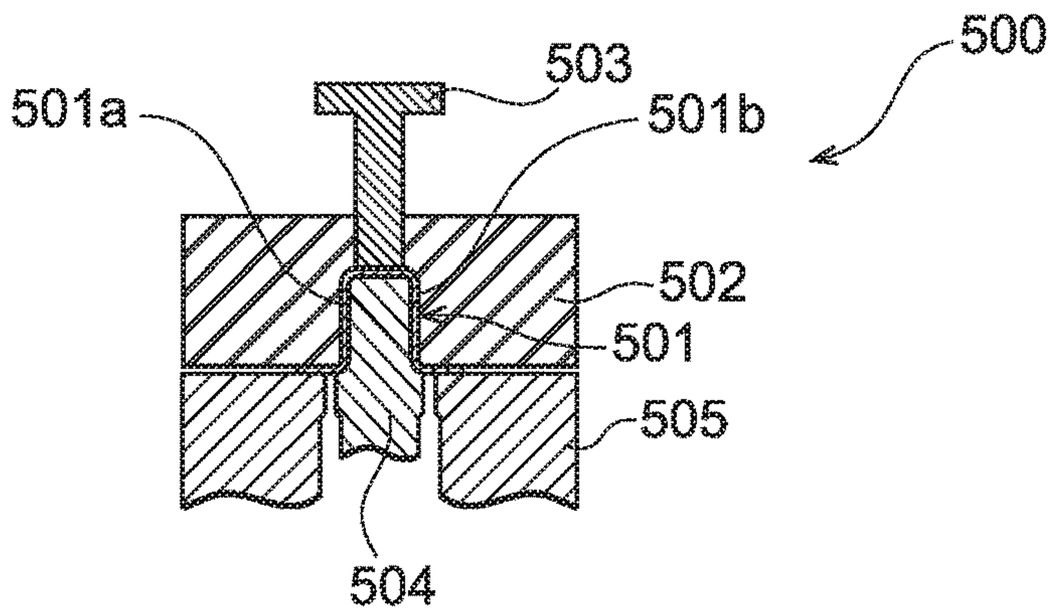


FIG.14E

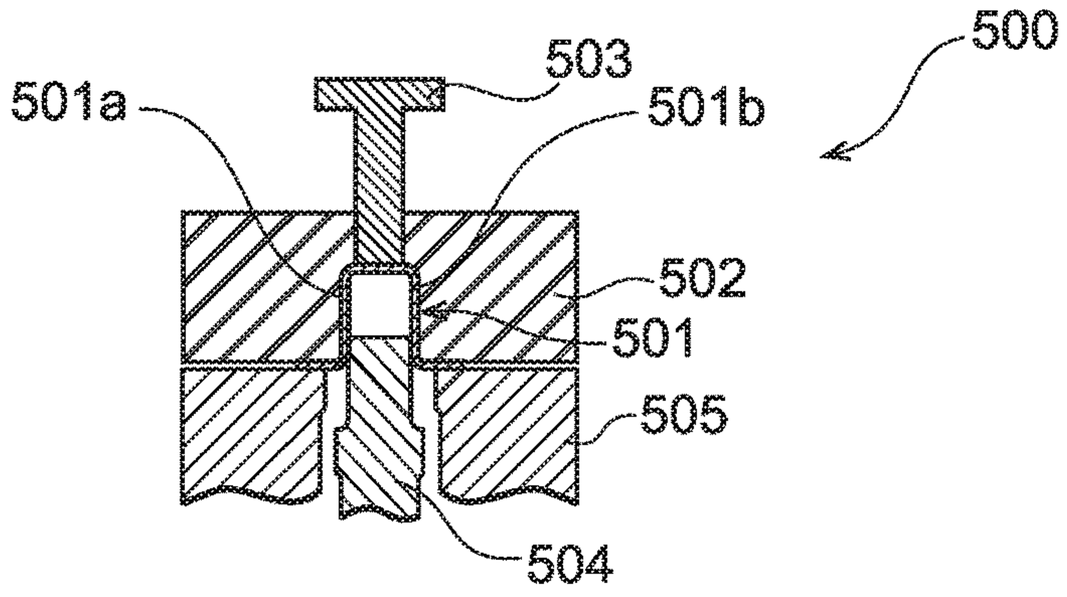


FIG.14F

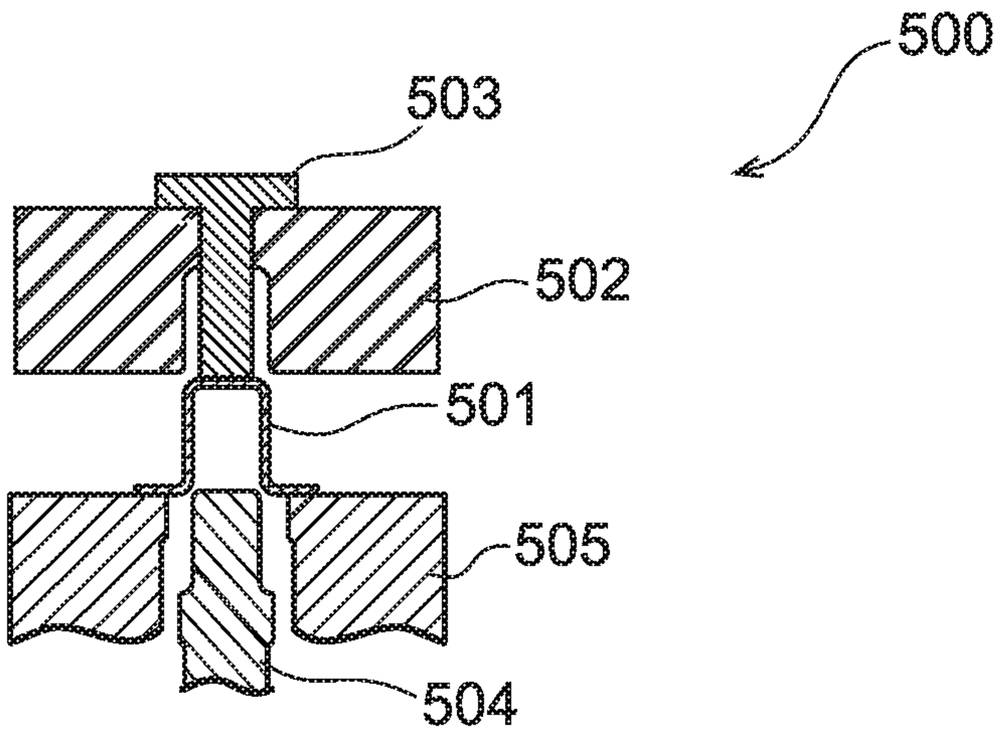


FIG.14G

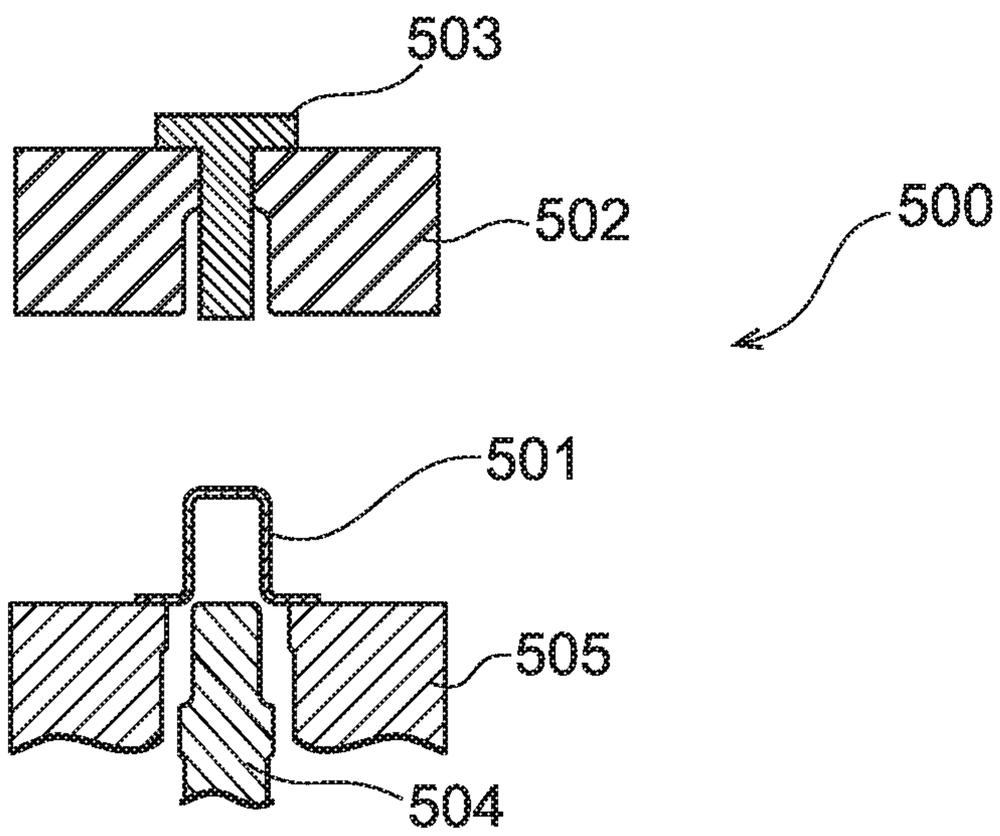


FIG.15A

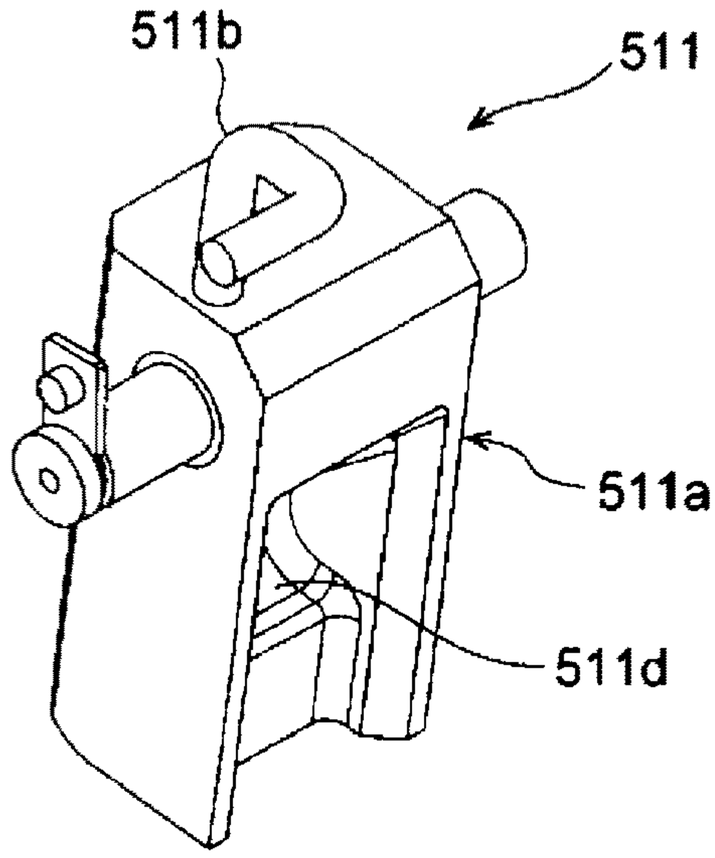


FIG.15B

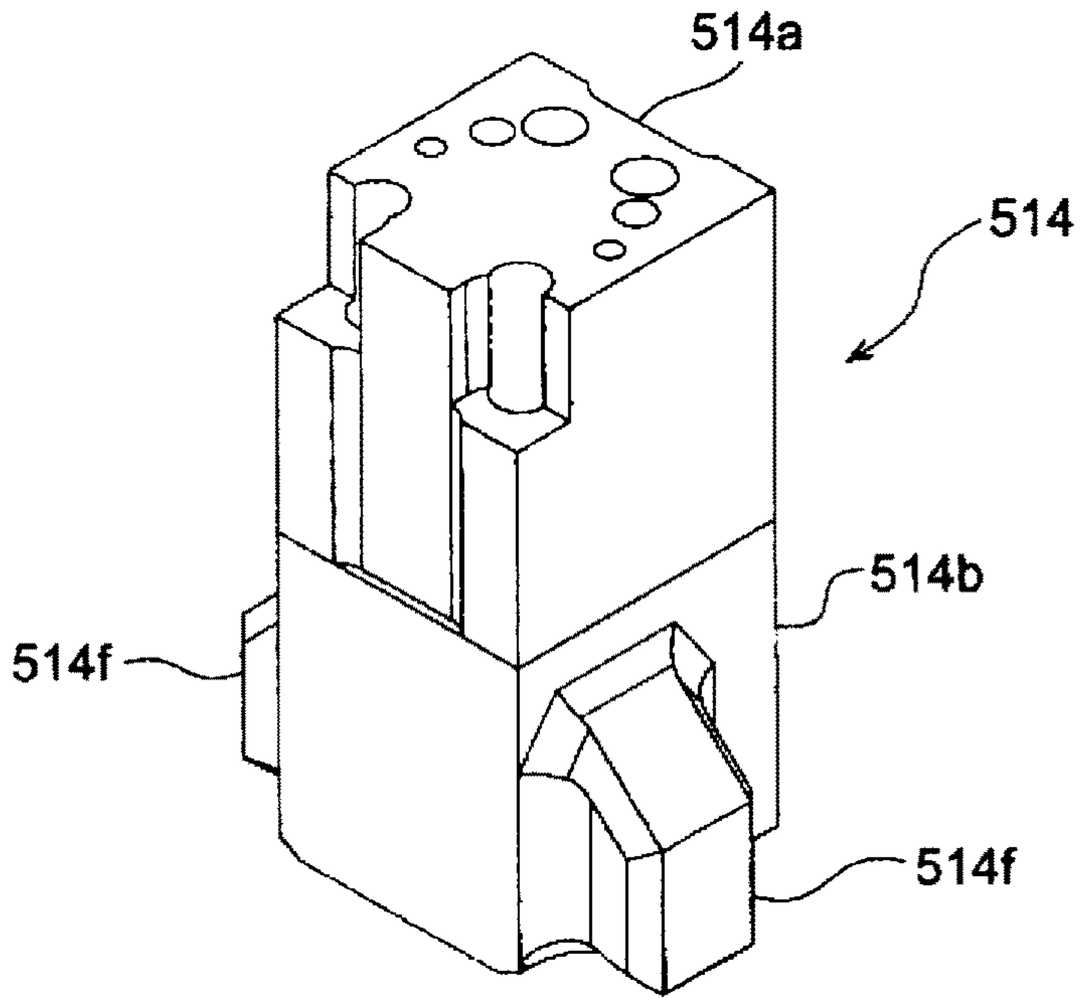


FIG.16A

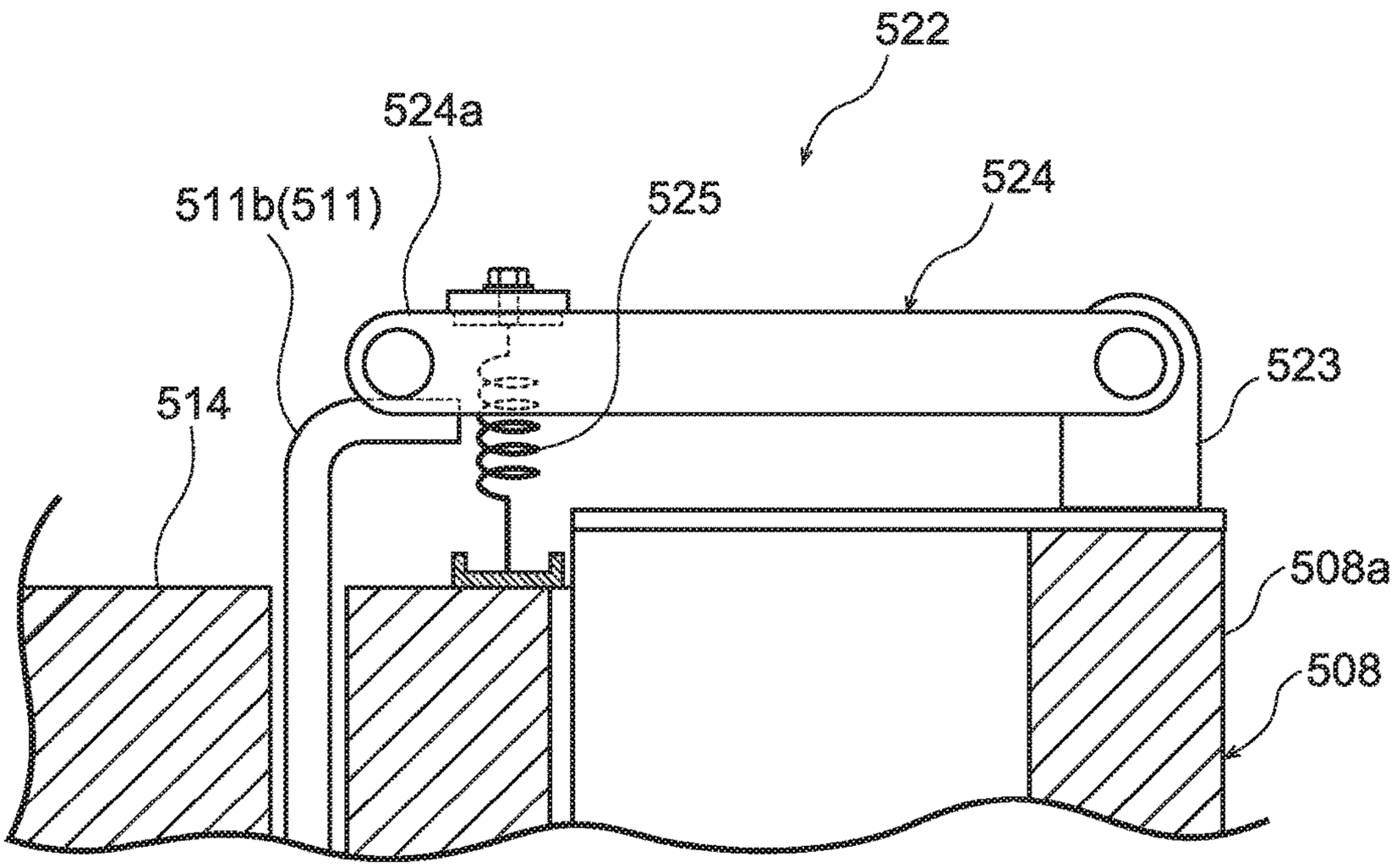
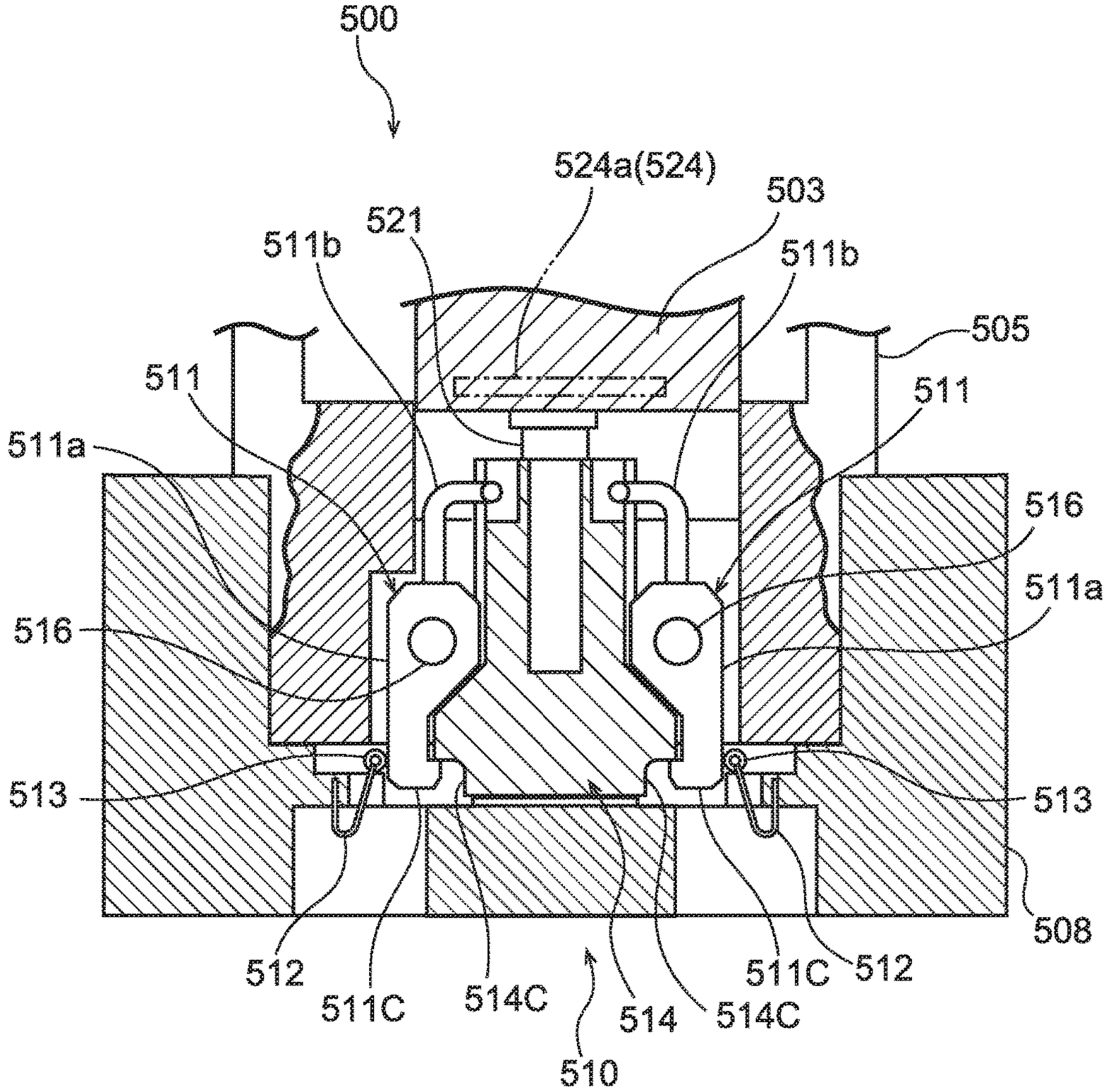


FIG.16B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524a(524)
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511b
511b
505
511
511
511a
516
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511a
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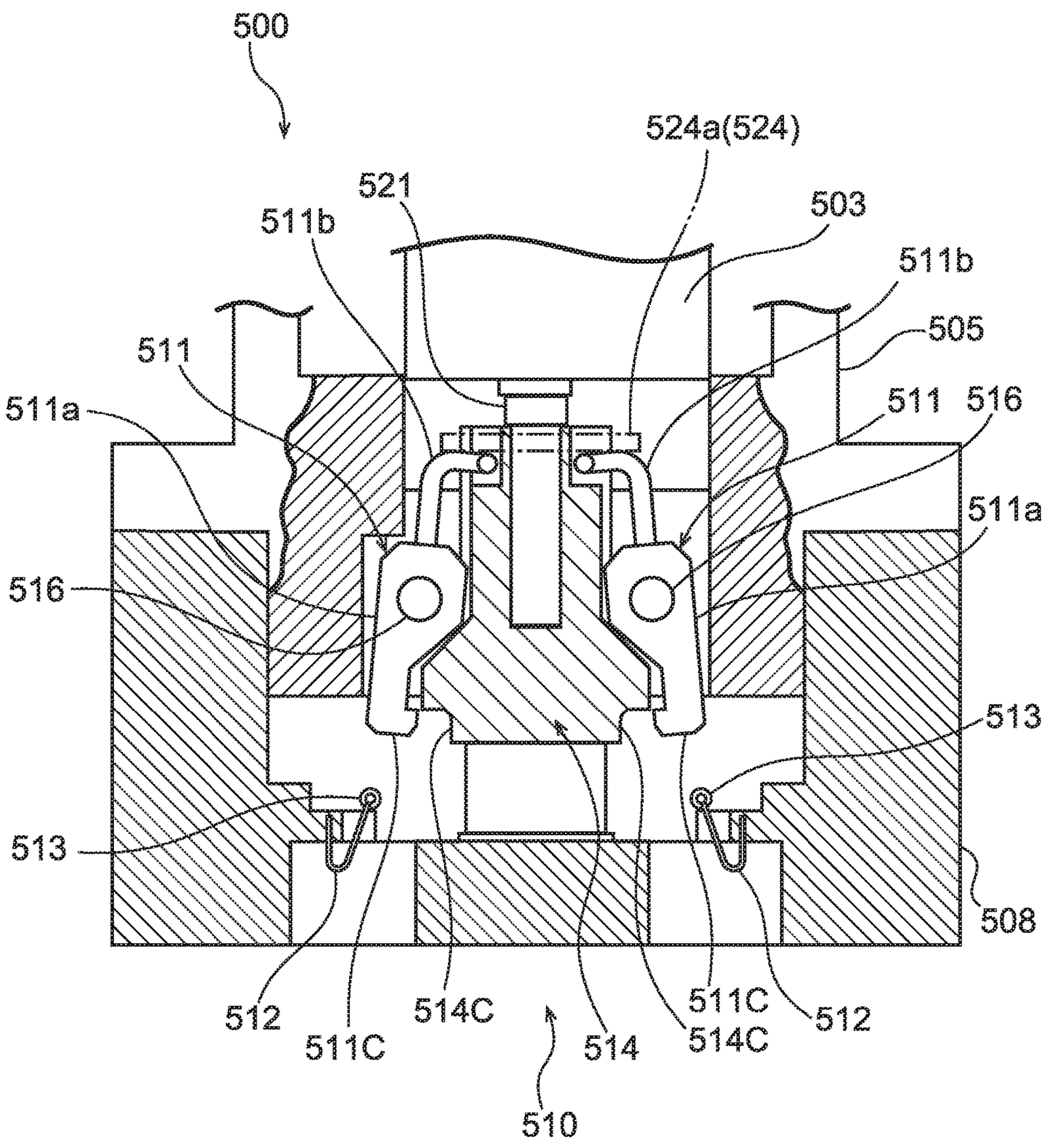
514C
511C
512
510

FIG.16C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503
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511b
505
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511C
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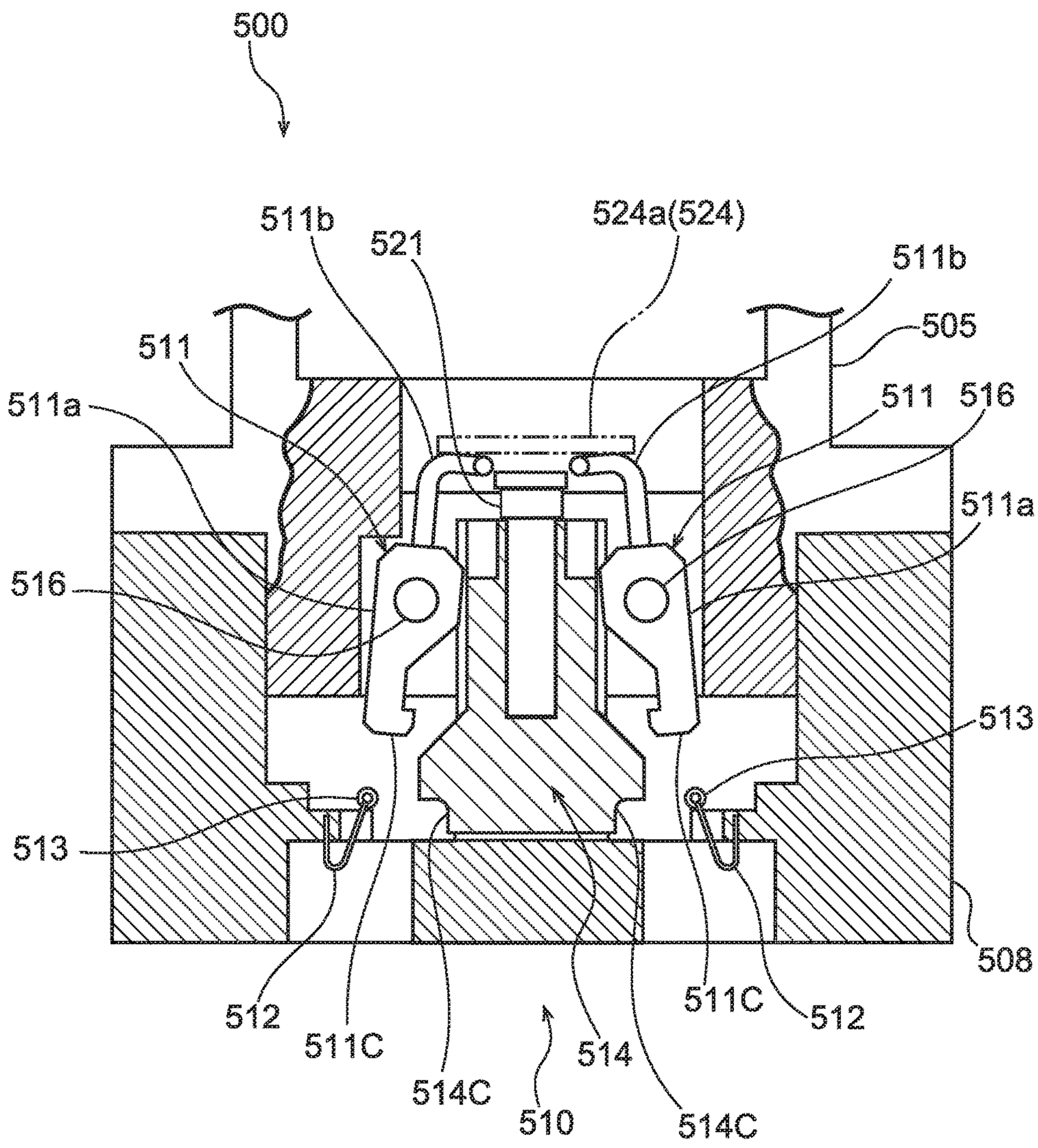
511C
514C
512
510

FIG.16D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514C
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FIG.17A

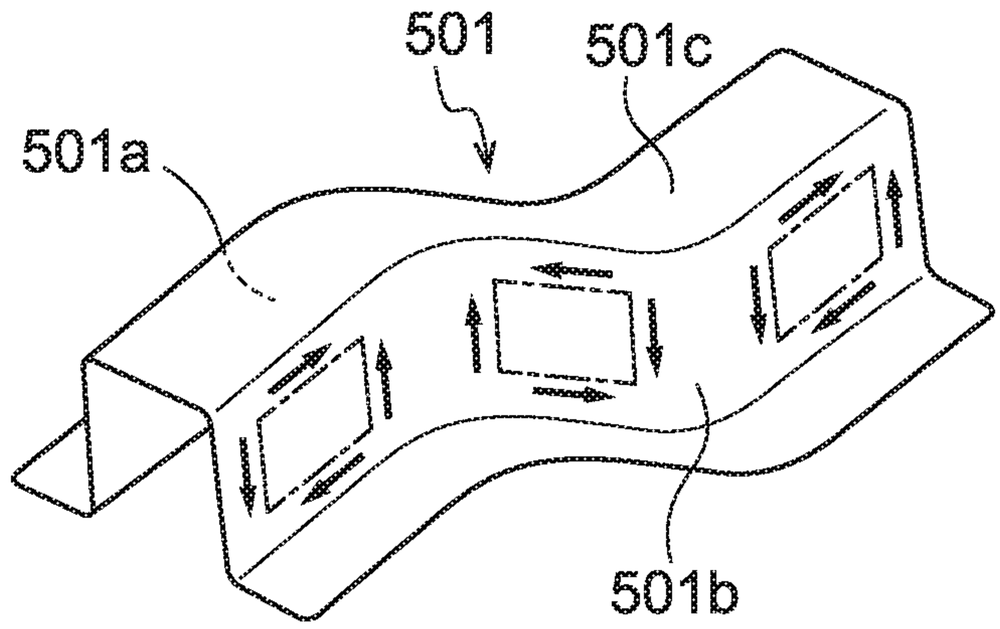


FIG.17B

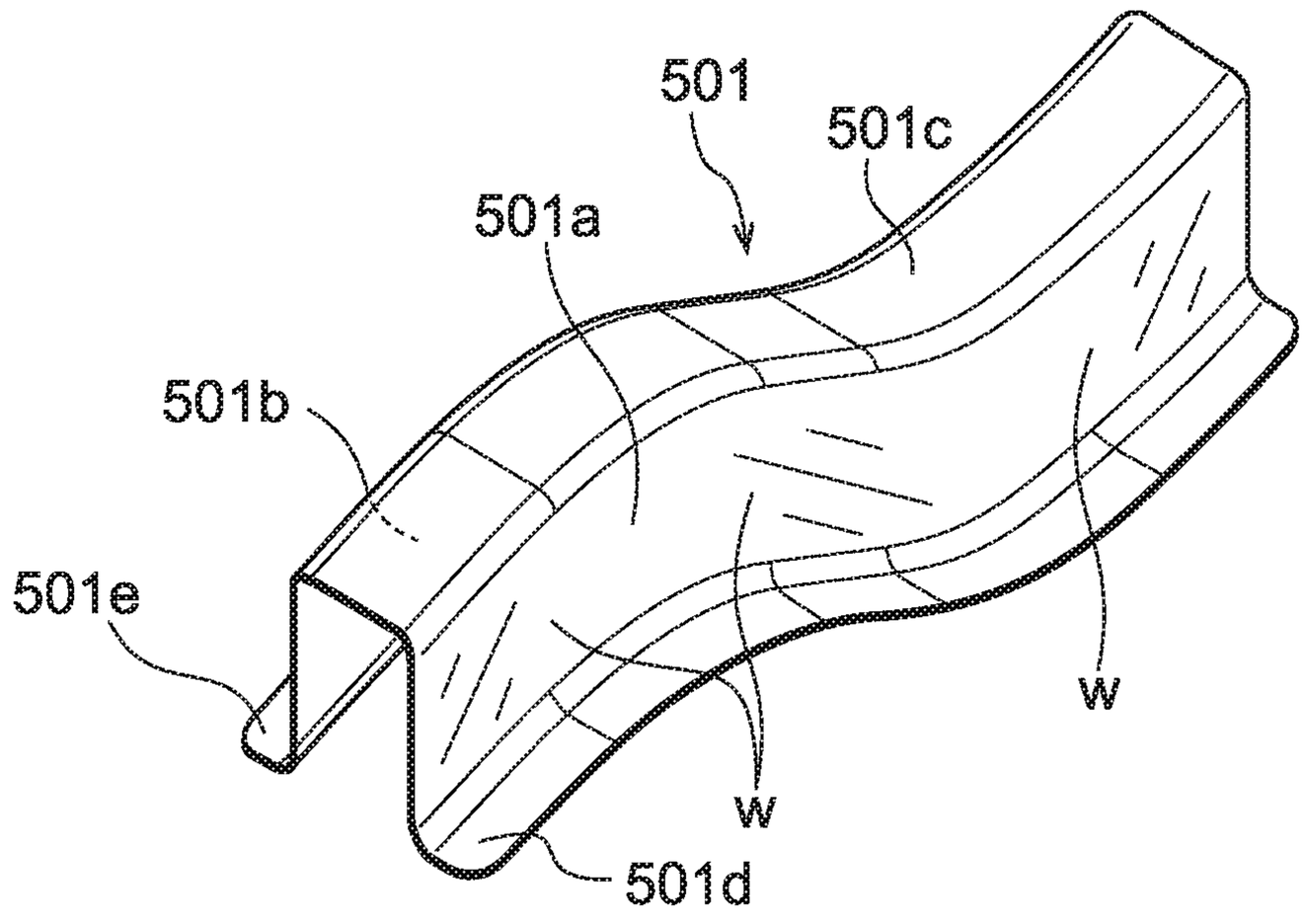


FIG.17C

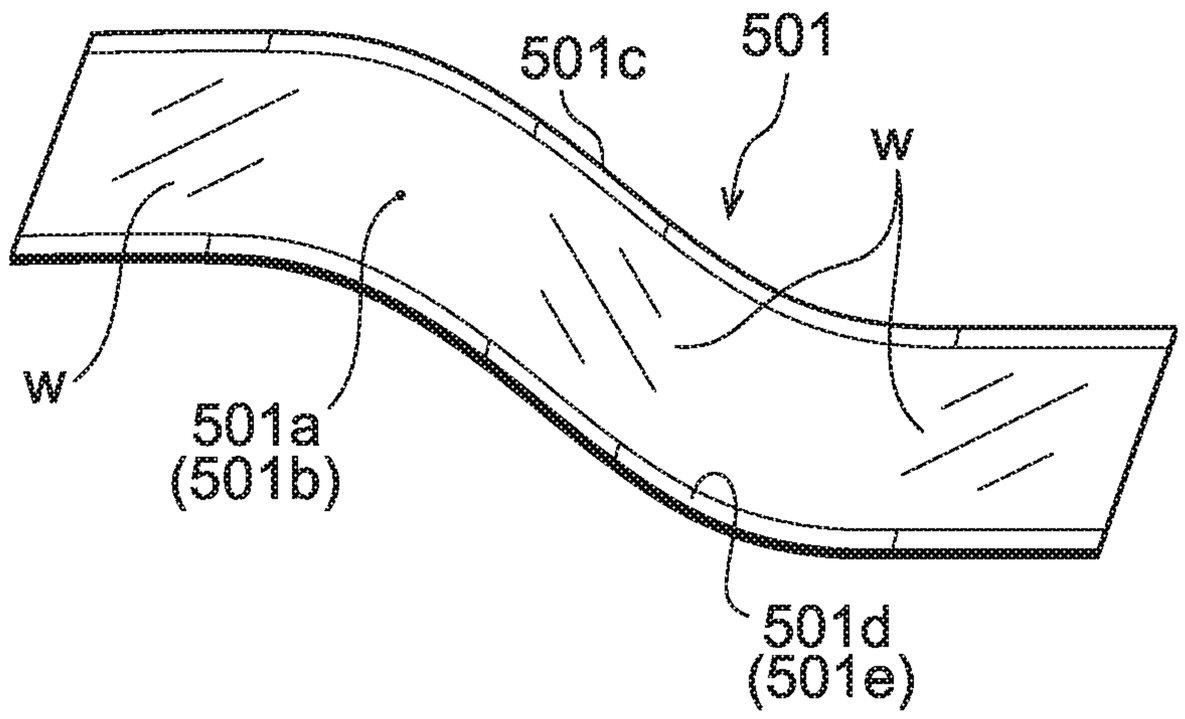


FIG.18A

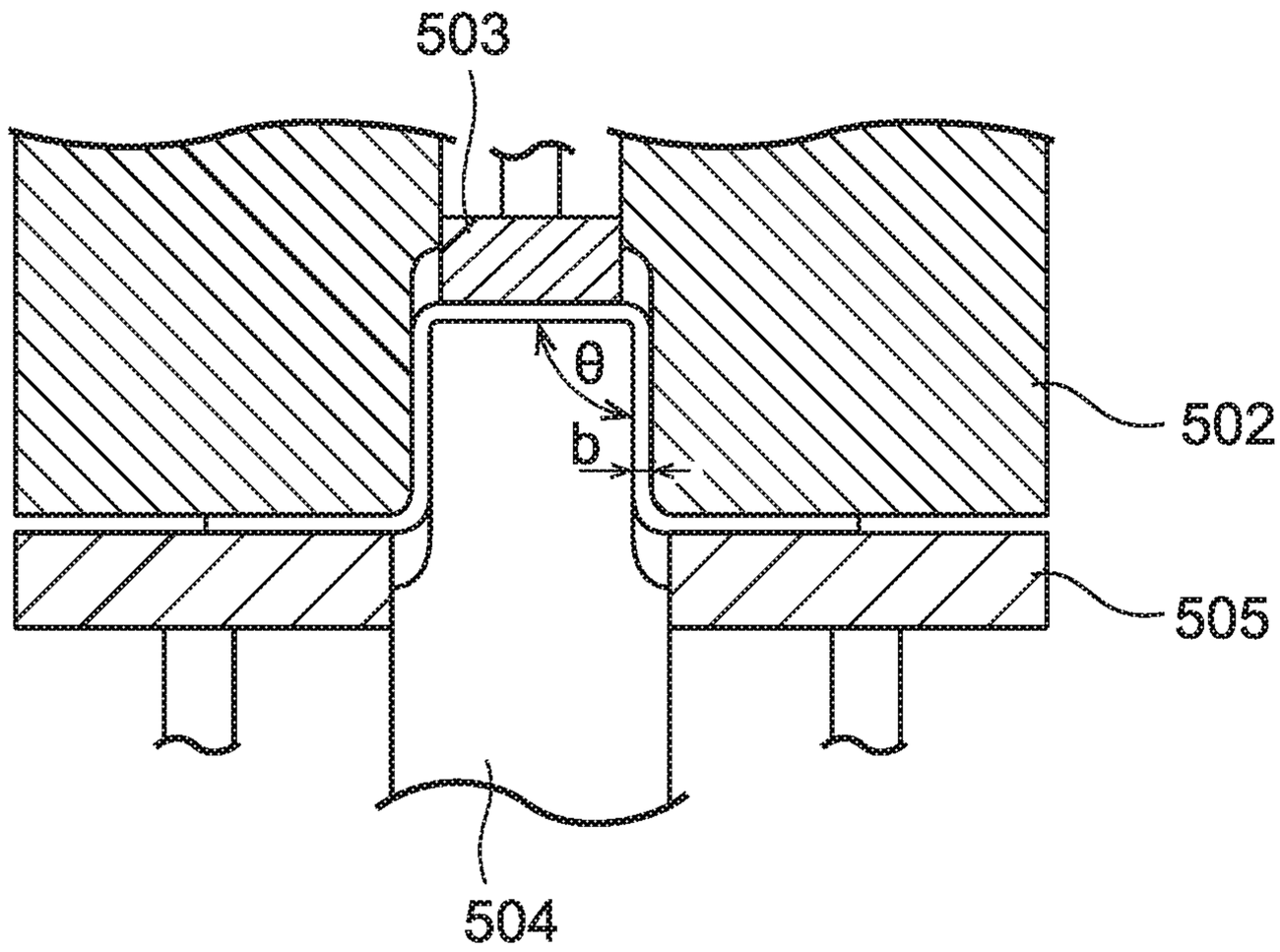


FIG.18B

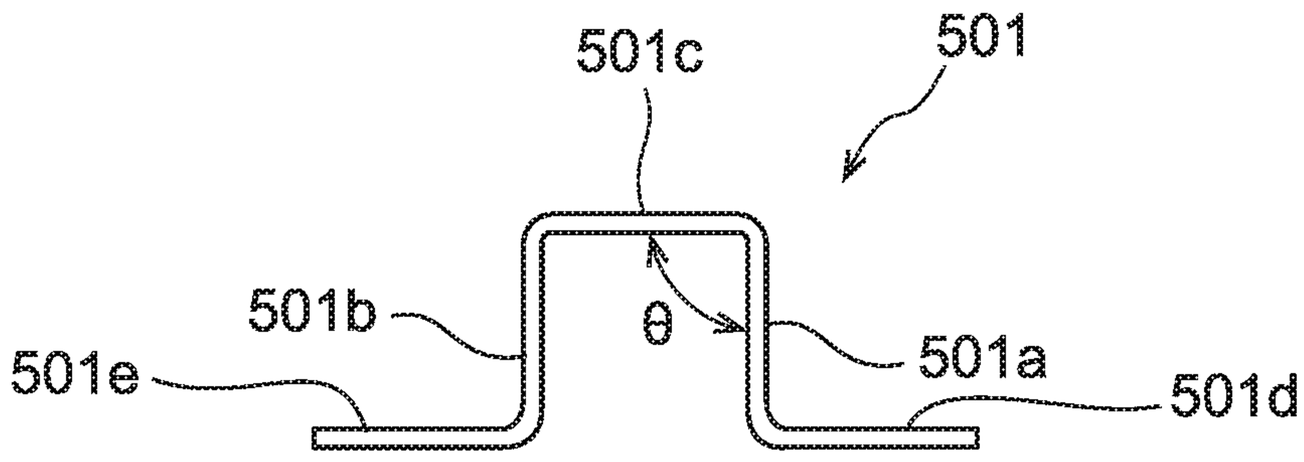


FIG.18C

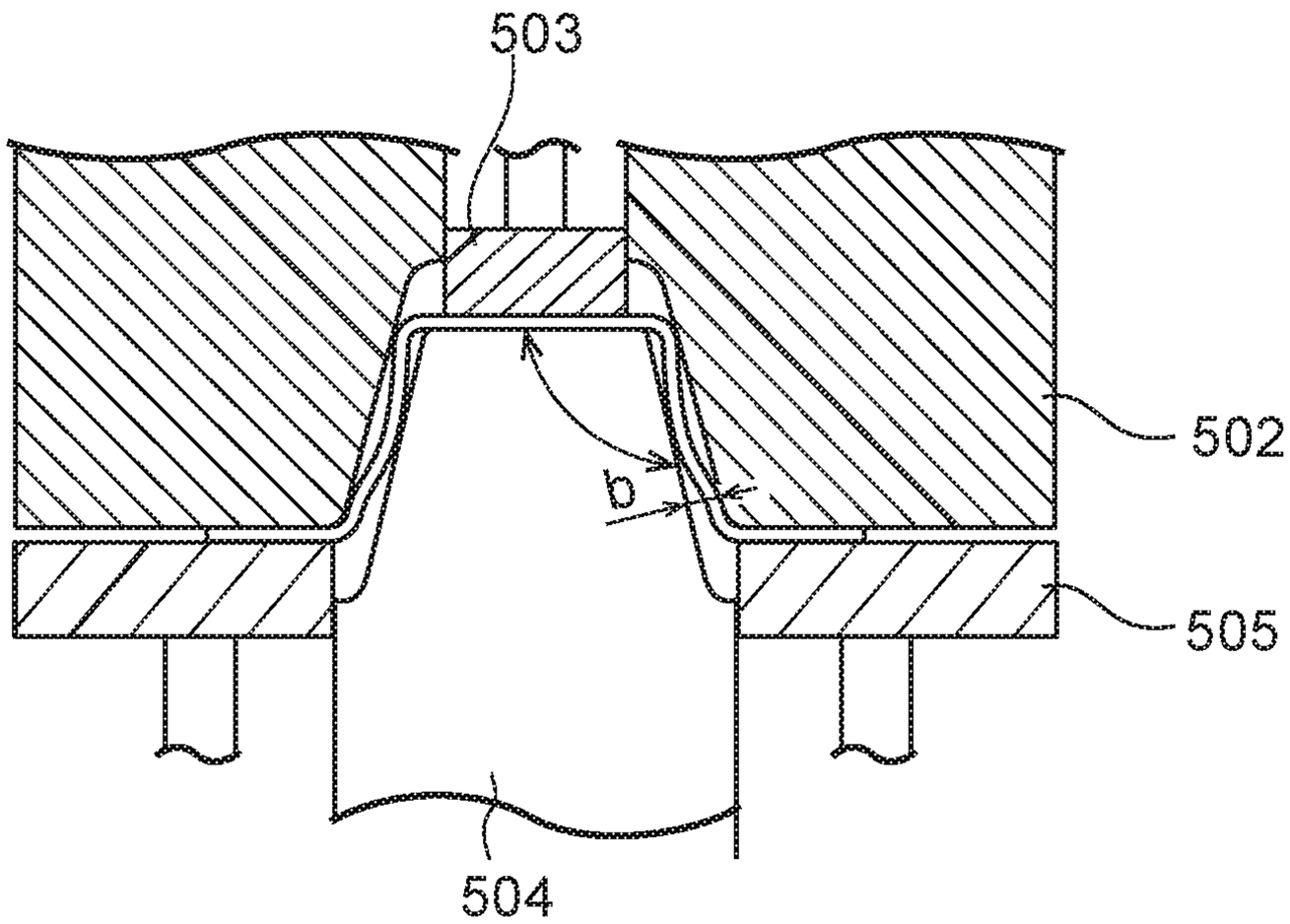


FIG.18D

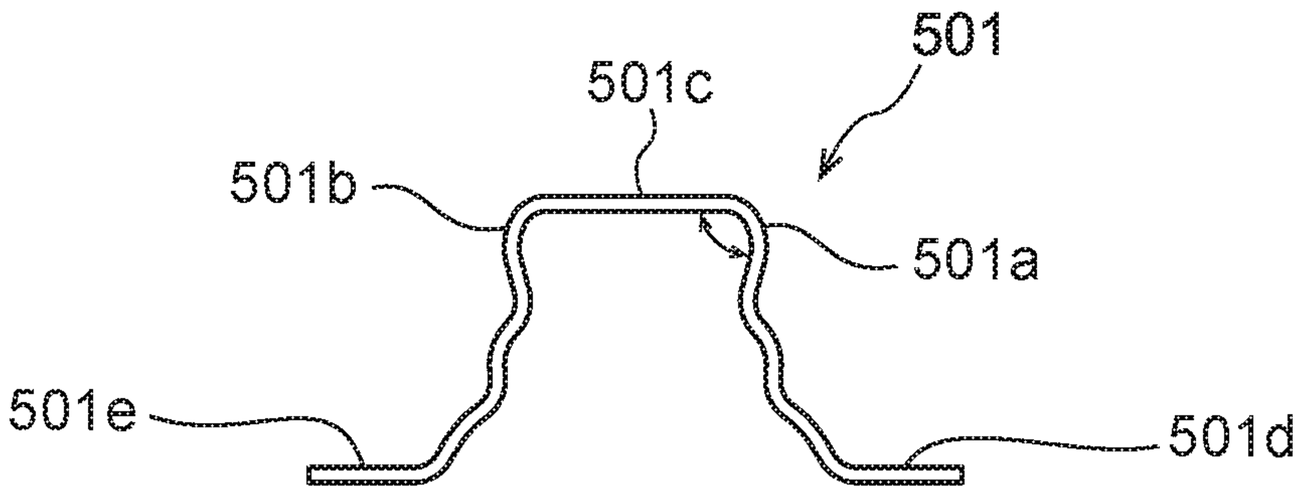


FIG.19A

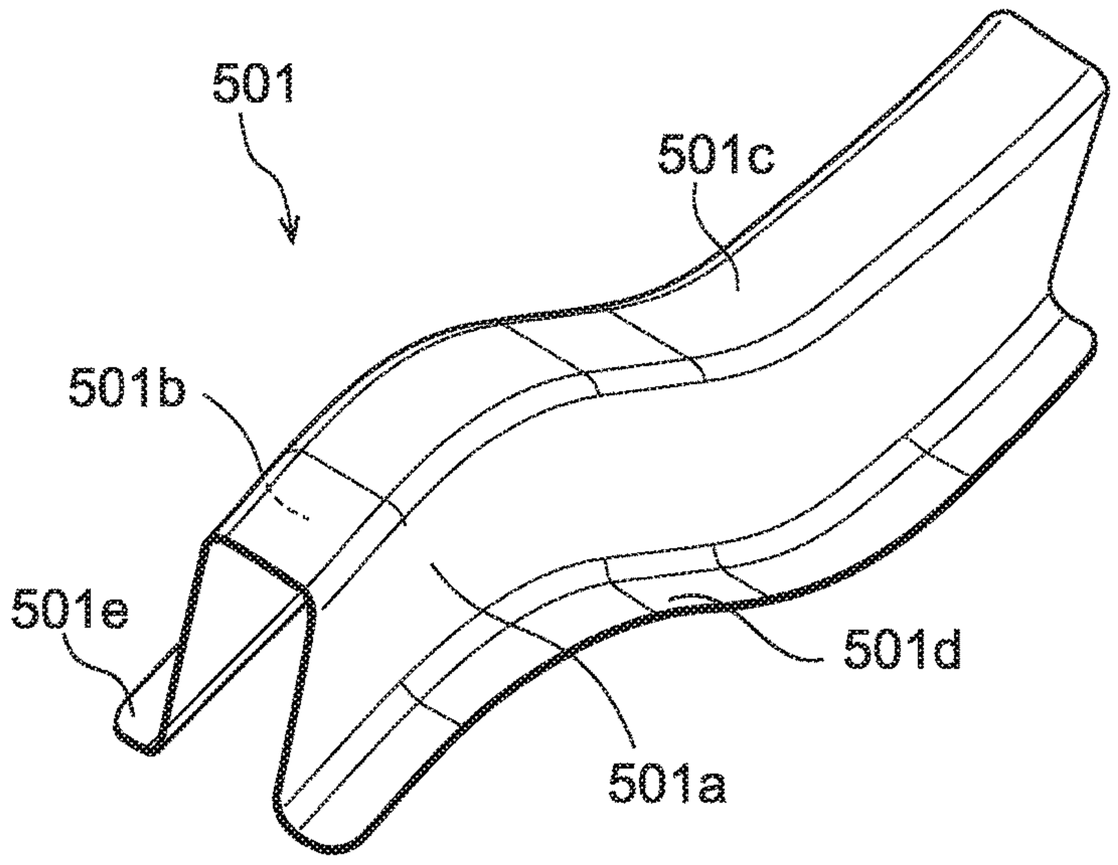


FIG.19B

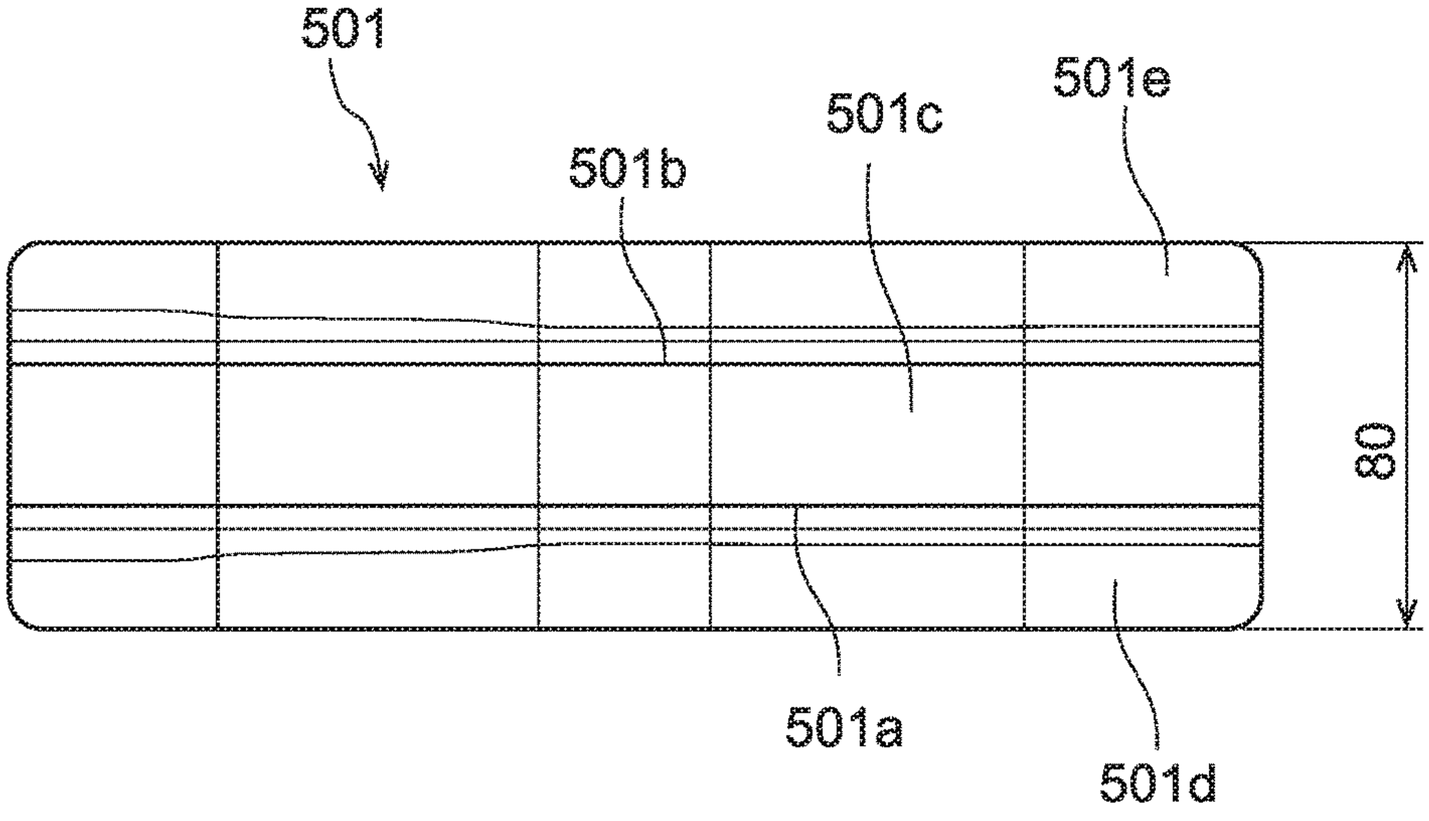


FIG.19C

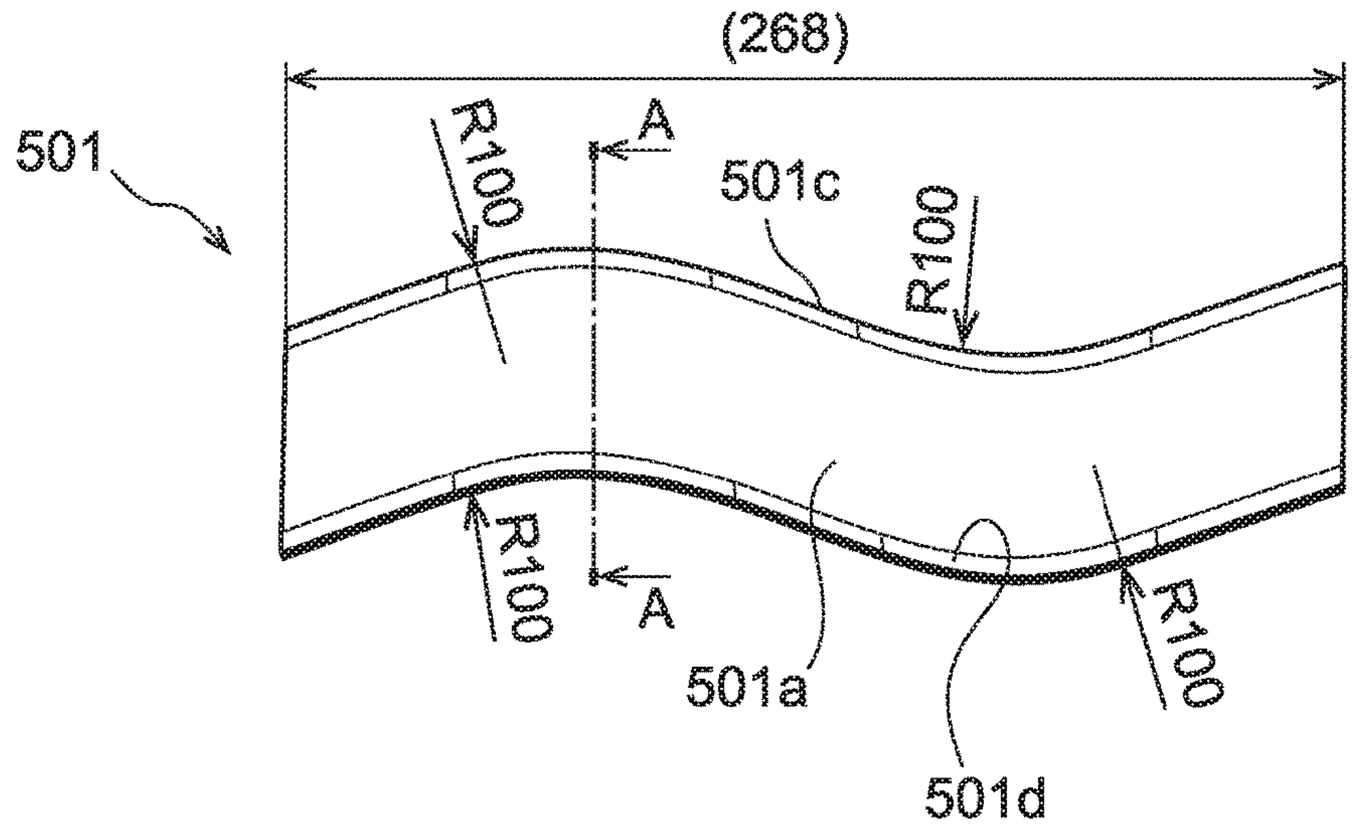
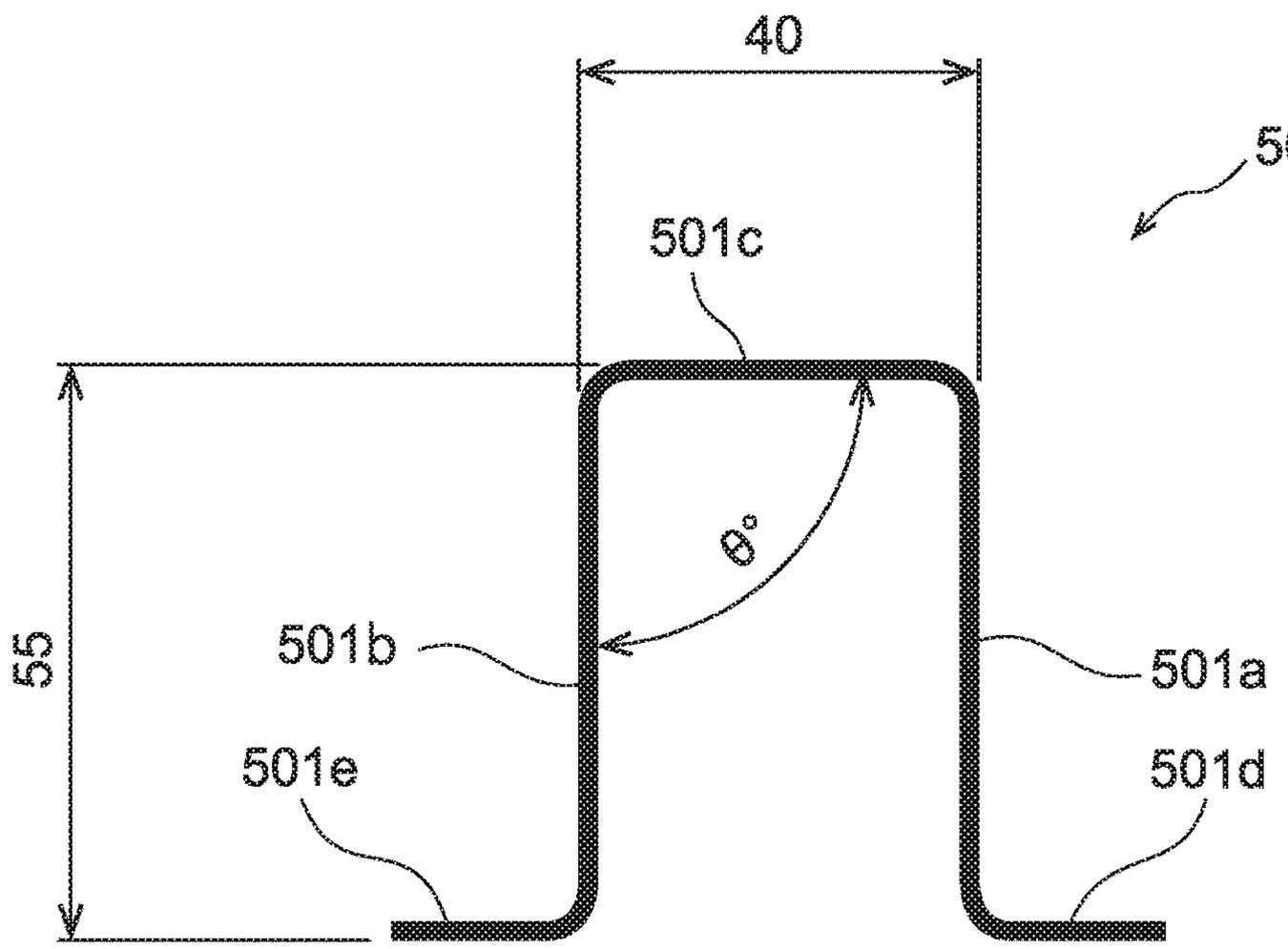
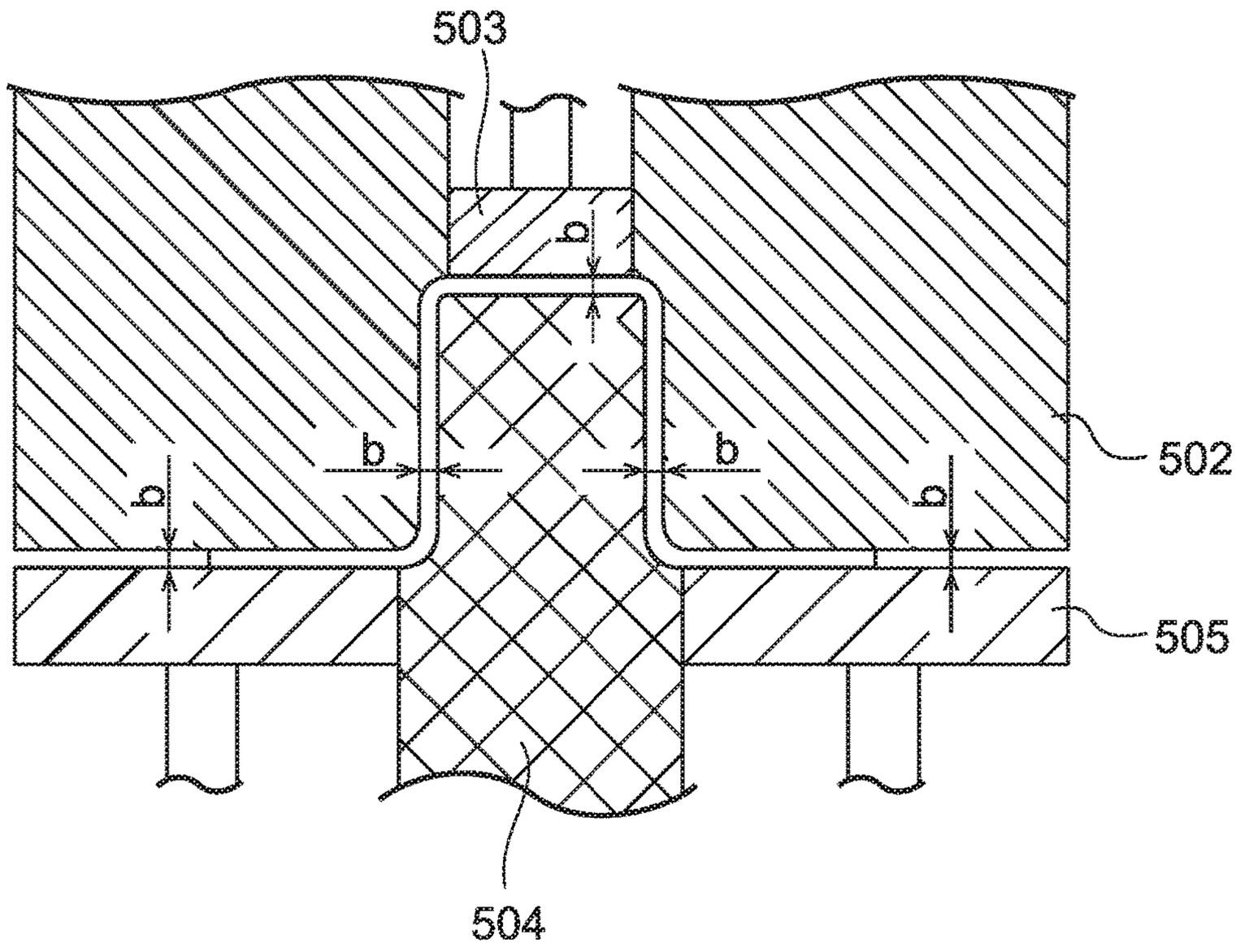


FIG.19D



CROSS-SECTION AA

FIG.20



HAT-SHAPED CROSS-SECTION COMPONENT MANUFACTURING APPARATUS AND MANUFACTURING METHOD

TECHNICAL FIELD

The present invention relates to a hat-shaped cross-section component manufacturing apparatus for and a manufacturing method for manufacturing a component with a hat-shaped cross-section.

BACKGROUND ART

Pressed components with a hat-shaped cross-section profile (also referred to as "hat-shaped cross-section components" in the present specification), such as front side members, are known structural members configuring automotive vehicle body framework. Such hat-shaped cross-section components are formed by performing press working (drawing) or the like on metal sheet materials (for example, steel sheets) (see, for example, Japanese Patent Application Laid-Open (JP-A) Nos. 2003-103306, 2004-154859, 2006-015404, and 2008-307557).

SUMMARY OF INVENTION

Technical Problem

When a hat-shaped cross-section component is formed by drawing a metal sheet, it is important to remove the hat-shaped cross-section component during demolding while avoiding deformation as much as possible.

In consideration of the above circumstances, an object of the present invention is to obtain a hat-shaped cross-section component manufacturing apparatus capable of suppressing deformation of a hat-shaped cross-section component during demolding.

Solution to Problem

A hat-shaped cross-section component manufacturing apparatus that addresses the above issue includes: a die that includes a forming face that presses both side portions of a metal sheet, and that includes an opening; a punch that is disposed facing the opening of the die, wherein the punch is disposed inside the opening when a mold is closed, and wherein the punch includes a forming face that presses a central portion of the metal sheet; a pad that is disposed inside the opening formed in the die, wherein the pad includes a forming face that presses and grips the central portion of the metal sheet against the punch when the mold is closed so as to configure a forming face corresponding to the forming face of the punch; a holder that is disposed facing the die, wherein the holder includes a forming face that presses and grips both side portions of the metal sheet against the die when the mold is closed so as to configure a forming face corresponding to the forming face of the die; and a pressure limiting device that includes a pressure limiting section that moves together with the holder during demolding after forming a hat-shaped cross-section component with a hat shaped cross-section, wherein the pressure limiting device is interposed between the pad and the holder, and wherein the pressure limits pressing on the hat-shaped cross-section component by the pad and the holder.

A hat-shaped cross-section component manufacturing method that addresses the above issue employs the hat-shaped cross-section component manufacturing apparatus above, and includes: a forming process of forming the hat-shaped cross-section component by configuring a metal sheet that is curved up-down by gripping the central portion of the metal sheet between the punch and the pad, and gripping the both side portions of the metal sheet between the die and the holder, and moving the holder and die, and the punch and pad, up-down relative to each other; and a demolding process of demolding the hat-shaped cross-section component by moving one or both out of the die or the blank holder in a demolding direction in a state in which the pad and the pressure limiting section are in contact with each other.

In the hat-shaped cross-section component manufacturing apparatus and the hat-shaped cross-section component manufacturing method that address the above issue, the hat-shaped cross-section component that has a hat-shaped cross-section profile is formed by gripping the central portion of the metal sheet with the punch and the pad, gripping the both side portions of the metal sheet with the die and the holder, and moving the holder and die, and the punch and pad, up-down relative to each other. Then, the pressure limiting section is interposed between the pad and the holder, and one or both out of the die or the blank holder are moved in a demolding direction in a state in which pressing on the hat-shaped cross-section component by the pad and the holder is limited. The hat-shaped cross-section component is thereby removed from the mold (the holder, the die, the punch, and the pad) in a state in which pressing of the formed hat-shaped cross-section component between the pad and the holder is limited during demolding.

Advantageous Effects of Invention

The hat-shaped cross-section component manufacturing apparatus and manufacturing method of the present invention exhibit the excellent advantageous effect of enabling deformation of a hat-shaped cross-section component during demolding to be suppressed.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1**A is a perspective view illustrating an example of a curving component configured with a hat-shaped cross-section.

FIG. **1**B is a plan view of the curving component illustrated in FIG. **1**A, as viewed from above.

FIG. **1**C is a front view of the curving component illustrated in FIG. **1**A.

FIG. **1**D is a side view of the curving component illustrated in FIG. **1**A, as viewed from one end portion.

FIG. **2** is a perspective view corresponding to FIG. **1**A, illustrating a curving component in order to explain ridge lines at locations corresponding to a concave shaped curved portion and a convex shaped curved portion.

FIG. **3**A is a perspective view illustrating a metal stock sheet before forming.

FIG. **3**B is a perspective view illustrating a drawn panel.

FIG. **4** is a perspective view corresponding to FIG. **3**B, illustrating locations in the drawn panel where cracks and creases are liable to occur.

FIG. **5** is an exploded perspective view illustrating relevant portions of a hat-shaped cross-section component manufacturing apparatus.

FIG. **6**A is a cross-section illustrating a stage at the start of processing of the hat-shaped cross-section component manufacturing apparatus illustrated in FIG. **5**.

FIG. **6**B is a cross-section illustrating the hat-shaped cross-section component manufacturing apparatus illustrated in FIG. **5** at a stage at which a metal stock sheet is gripped and restrained between a die and pad, and a holder and a punch.

FIG. **6**C is a cross-section illustrating a stage at which the punch has been pushed in from the stage illustrated in FIG. **6**B.

FIG. **6**D is a cross-section illustrating a state in which the punch has been pushed in further from the stage illustrated in FIG. **6**C, such that the punch has been fully pushed in with respect to the die.

FIG. **7** is an exploded perspective view illustrating another hat-shaped cross-section component manufacturing apparatus.

FIG. **8**A is a cross-section illustrating the hat-shaped cross-section component manufacturing apparatus illustrated in FIG. **7**, at a stage at the start of processing.

FIG. **8**B is a cross-section illustrating a stage at which the metal stock sheet is gripped and restrained between a die and pad, and a holder and punch of the hat-shaped cross-section component manufacturing apparatus illustrated in FIG. **7**.

FIG. **8**C is a cross-section illustrating a stage at which the punch has been pushed in from the stage illustrated in FIG. **8**B.

FIG. **8**D is a cross-section illustrating a state in which the punch has been pushed in further from the stage illustrated in FIG. **8**C, such that the punch has been fully pushed in with respect to the die.

FIG. **9**A is a cross-section illustrating a mold to explain a defect that occurs when removing a curving component from the mold after a punch has been fully pushed into a die and a metal stock sheet has been formed into the curving component.

FIG. **9**B is a cross-section illustrating the mold at a stage in which the punch is being retracted from the die from the state illustrated in FIG. **9**A.

FIG. **9**C is a cross-section illustrating the mold at a stage in which the punch has been fully retracted from the die from the state illustrated in FIG. **9**B.

FIG. **10**A is a cross-section illustrating a mold, in a state in which a punch has been fully pushed into a die.

FIG. **10**B is a cross-section illustrating the mold at a stage in which the punch is being retracted from the die from the state illustrated in FIG. **10**A.

FIG. **10**C is a cross-section illustrating the mold at a stage in which the punch has been fully retracted from the die from the state illustrated in FIG. **10**B.

FIG. **11**A is a cross-section illustrating a mold, in a state in which a punch has been fully pushed into a die.

FIG. **11**B is a cross-section illustrating the mold at a stage in which the punch is being retracted from the die from the state illustrated in FIG. **11**A.

FIG. **11**C is a cross-section illustrating the mold at a stage in which the punch has been fully retracted from the die from the state illustrated in FIG. **11**B.

FIG. **12**A is a perspective view illustrating a pressure limiting device.

FIG. **12**B is a perspective view illustrating a base plate to which a punch is fixed, and floating blocks configuring a portion of a pressure limiting device.

FIG. **12**C is a perspective view illustrating a blank holder.

FIG. **12**D is a perspective view illustrating floating blocks incorporated into a blank holder.

FIG. **12**E is a partial plan view cross-section illustrating a location where a pressure limiting device is provided in a hat-shaped cross-section component manufacturing apparatus.

FIG. **13**A is an explanatory diagram illustrating a cross-section of a hat-shaped cross-section component manufacturing apparatus over time, as taken along line A-A in FIG. **12**B, FIG. **12**C, and FIG. **12**E.

FIG. **13**B is an explanatory diagram illustrating a cross-section of a hat-shaped cross-section component manufacturing apparatus over time, as taken along line A-A in FIG. **12**B, FIG. **12**C, and FIG. **12**E, illustrating the cross-section at a later timing than in FIG. **13**A.

FIG. **13**C is an explanatory diagram illustrating a cross-section of a hat-shaped cross-section component manufacturing apparatus over time, as taken along line A-A in FIG. **12**B, FIG. **12**C, and FIG. **12**E, illustrating the cross-section at a later timing than in FIG. **13**B.

FIG. **13**D is an explanatory diagram illustrating a cross-section of a hat-shaped cross-section component manufacturing apparatus over time, as taken along line A-A in FIG. **12**B, FIG. **12**C, and FIG. **12**E, illustrating the cross-section at a later timing than in FIG. **13**C.

FIG. **13**E is an explanatory diagram illustrating a cross-section of a hat-shaped cross-section component manufacturing apparatus over time, as taken along line A-A in FIG. **12**B, FIG. **12**C, and FIG. **12**E, illustrating the cross-section at a later timing than in FIG. **13**D.

FIG. **13**F is an explanatory diagram illustrating a cross-section of a hat-shaped cross-section component manufacturing apparatus over time, as taken along line A-A in FIG. **12**B, FIG. **12**C, and FIG. **12**E, illustrating the cross-section at a later timing than in FIG. **13**E.

FIG. **13**G is an explanatory diagram illustrating a cross-section of a hat-shaped cross-section component manufacturing apparatus over time, as taken along line A-A in FIG. **12**B, FIG. **12**C, and FIG. **12**E, illustrating the cross-section at a later timing than in FIG. **13**F.

FIG. **14**A is an explanatory diagram illustrating a cross-section of a hat-shaped cross-section component manufacturing apparatus over time, as taken along line B-B in FIG. **12**B, FIG. **12**C, and FIG. **12**E, illustrating the cross-section at the same timing as in FIG. **13**A.

FIG. **14**B is an explanatory diagram illustrating a cross-section of a hat-shaped cross-section component manufacturing apparatus over time, as taken along line B-B in FIG. **12**B, FIG. **12**C, and FIG. **12**E, illustrating the cross-section at the same timing as in FIG. **13**B.

FIG. **14**C is an explanatory diagram illustrating a cross-section of a hat-shaped cross-section component manufacturing apparatus over time, as taken along line B-B in FIG. **12**B, FIG. **12**C, and FIG. **12**E, illustrating the cross-section at the same timing as in FIG. **13**C.

FIG. **14**D is an explanatory diagram illustrating a cross-section of a hat-shaped cross-section component manufacturing apparatus over time, as taken along line B-B in FIG. **12**B, FIG. **12**C, and FIG. **12**E, illustrating the cross-section at the same timing as in FIG. **13**D.

FIG. **14**E is an explanatory diagram illustrating a cross-section of a hat-shaped cross-section component manufacturing apparatus over time, as taken along line B-B in FIG. **12**B, FIG. **12**C, and FIG. **12**E, illustrating the cross-section at the same timing as in FIG. **13**E.

FIG. **14**F is an explanatory diagram illustrating a cross-section of a hat-shaped cross-section component manufacturing apparatus over time, as taken along line B-B in FIG.

12B, FIG. 12C, and FIG. 12E, illustrating the cross-section at the same timing as in FIG. 13F.

FIG. 14G is an explanatory diagram illustrating a cross-section of a hat-shaped cross-section component manufacturing apparatus over time, as taken along line B-B in FIG. 12B, FIG. 12C, and FIG. 12E, illustrating the cross-section at the same timing as in FIG. 13G.

FIG. 15A is a perspective view illustrating a holding arm of another embodiment.

FIG. 15B is a perspective view illustrating floating blocks of another embodiment.

FIG. 16A is a side view illustrating a retention release section provided to the base plate illustrated in FIG. 12B.

FIG. 16B is an explanatory diagram corresponding to FIG. 13D, illustrating a cross-section of a hat-shaped cross-section component manufacturing apparatus including the retention release section illustrated in FIG. 16A over time.

FIG. 16C is an explanatory diagram corresponding to FIG. 13F, illustrating a cross-section of a hat-shaped cross-section component manufacturing apparatus including the retention release section illustrated in FIG. 16A over time.

FIG. 16D is an explanatory diagram corresponding to FIG. 13G, illustrating a cross-section of a hat-shaped cross-section component manufacturing apparatus including the retention release section illustrated in FIG. 16A over time.

FIG. 17A is a perspective view of a curving component, schematically illustrating stress occurring in vertical walls.

FIG. 17B is a perspective view of the curving component, illustrating shear creasing occurring in the vertical walls.

FIG. 17C is a side view of the curving component, illustrating shear creasing occurring in the vertical walls.

FIG. 18A is a cross-section of a hat-shaped cross-section component manufacturing apparatus to explain the dimensions and the like of respective portions in order to prevent the occurrence of shear creasing.

FIG. 18B is a cross-section of a curving component to explain the dimensions and the like of respective portions in order to prevent the occurrence of shear creasing.

FIG. 18C is a cross-section of a hat-shaped cross-section component manufacturing apparatus to explain the dimensions and the like of respective portions in order to prevent the occurrence of shear creasing.

FIG. 18D is cross-section of a curving component to explain the dimensions and the like of respective portions in order to prevent the occurrence of shear creasing.

FIG. 19A is a perspective view of a curving component manufactured by the hat-shaped cross-section component manufacturing apparatus illustrated in FIG. 5.

FIG. 19B is a plan view of the curving component illustrated in FIG. 19A, as viewed from above.

FIG. 19C is a side view of the curving component illustrated in FIG. 19A.

FIG. 19D is a front view of the curving component illustrated in FIG. 19A, as viewed from one end portion.

FIG. 20 is a cross-section of a mold, illustrating the clearance b in Table 1.

DESCRIPTION OF EMBODIMENTS

Explanation follows regarding a hat-shaped cross-section component manufacturing apparatus and manufacturing method according to an exemplary embodiment of the present invention. First, explanation follows regarding configuration of a hat-shaped cross-section component, followed by explanation regarding the hat-shaped cross-section component manufacturing apparatus and manufacturing method.

Hat-Shaped Cross-Section Component Configuration

FIG. 1A to FIG. 1D and FIG. 2 illustrate a curving component **10**, serving as a hat-shaped cross-section component manufactured by drawing using a hat-shaped cross-section component manufacturing apparatus **500** (see FIG. **5**) of the present exemplary embodiment. As illustrated in these drawings, the curving component **10** includes a top plate **11** extending along the length direction, and vertical walls **12***a*, **12***b*, that respectively bend and extend from both short end direction sides of the top plate **11** toward one side in the thickness direction of the top plate **11**. The curving component **10** further includes an outward extending flange **13***a* that bends from an end of the vertical wall **12***a* on the opposite side to the top plate **11**, and extends toward the side away from the vertical wall **12***b*, and an outward extending flange **13***b* that bends at an end of the vertical wall **12***b* on the opposite side to the top plate **11**, and extends toward the side away from the vertical wall **12***a*.

Ridge lines **14***a*, **14***b* are formed extending along the length direction of the curving component **10** between the top plate **11** and the respective vertical walls **12***a*, **12***b*. Concave lines **15***a*, **15***b* are formed extending along the length direction of the curving component **10** between the respective vertical walls **12***a*, **12***b* and outward extending flanges **13***a*, **13***b*.

The ridge lines **14***a*, **14***b* and the concave lines **15***a*, **15***b* are provided extending substantially parallel to each other. Namely, the height of the vertical walls **12***a*, **12***b* from the respective outward extending flanges **13***a*, **13***b* is substantially uniform along the length direction of the curving component **10**.

As illustrated in FIG. **2**, a portion of the top plate **11** is formed with a convex shaped curved portion **11***a* that curves in an arc shape toward the outside of the lateral cross-section profile of the hat shape, namely toward the outer surface side of the top plate **11**. Another portion of the top plate **11** is formed with a concave shaped curved portion **11***b* that curves in an arc shape toward the inside of the lateral cross-section profile of the hat shape, namely toward the inner surface side of the top plate **11**. The ridge lines **14***a*, **14***b* formed by the top plate **11** and the vertical walls **12***a*, **12***b* at the convex shaped curved portion **11***a* and the concave shaped curved portion **11***b* are also curved in arc shapes at locations **16***a*, **16***b*, and **17***a*, **17***b*, corresponding to the convex shaped curved portion **11***a* and the concave shaped curved portion **11***b*. Note that an "arc shape" is not limited to part of a perfect circle, and may be part of another curved line, such as of an ellipse, a hyperbola, or a sine wave.

The curving component **10** described above is formed by forming a drawn panel **301**, illustrated in FIG. **3**B, by drawing a rectangular shaped metal stock sheet **201**, serving as a metal sheet, illustrated in FIG. **3**A, and then trimming unwanted portions of the drawn panel **301**.

Incidentally, when the curving component **10** with a hat-shaped cross-section is manufactured by drawing, as illustrated in FIG. **4**, excess material is present at a concave shaped curved portion top plate **301***a* and a convex shaped curved portion flange **301***b* of the drawn panel **301** at the stage of forming the drawn panel **301**, and creases are liable to occur. Increasing restraint at the periphery of the metal stock sheet **201** during the forming process by, for example, raising the pressing force of a blank holder, or by adding locations for forming draw beads to the blank holder, thereby suppressing inflow of the metal stock sheet **201** into the blank holder, is known to be effective in suppressing the occurrence of creases.

However, when there is increased suppression of inflow of the metal stock sheet **201** into the blank holder, there is a large reduction in the sheet thickness of the drawn panel **301** at respective portions including a convex shaped curved portion top plate **301***c*, a concave shaped curved portion flange **301***d*, and both length direction end portions **301***e*, **301***e*. In examples in which the metal stock sheet **201** is a material with particularly low extensibility (for example high tensile steel), it is conceivable that cracking could occur at these respective portions.

Accordingly, in order not to allow creasing and cracking in the manufacture of curved components with a hat-shaped cross-section, such as front side members configuring part of a vehicle body framework, by pressing using drawing, it has been difficult to employ high strength materials with low extensibility as the metal stock sheet **201**, meaning that low strength materials with high extensibility have had to be employed.

However, the occurrence of such creasing and cracking can be suppressed through a curving component manufacturing process, described later, employing the hat-shaped cross-section component manufacturing apparatus **500** of the present exemplary embodiment.

Hat-Shaped Cross-Section Component Manufacturing Apparatus Configuration

FIG. **5** is an exploded perspective view of the hat-shaped cross-section component manufacturing apparatus **500** employed to manufacture a curving component **501**, serving as a hat-shaped cross-section component. Note that configuration of the curving component **501** is substantially the same as the configuration of the curving component **10** (see FIG. **1**A). FIG. **6**A is a cross-section illustrating the manufacturing apparatus illustrated in FIG. **5** at the start of processing. FIG. **6**B is a cross-section illustrating the manufacturing apparatus illustrated in FIG. **5** at a stage at which a metal stock sheet **601** is gripped and restrained between a die **502** and pad **503**, and a blank holder **505** and punch **504**. FIG. **6**C is a cross-section illustrating a stage at which the punch **504** has been pushed in from the stage illustrated in FIG. **6**B. FIG. **6**D is a cross-section illustrating a state in which the punch **504** has been pushed in further from the stage illustrated in FIG. **6**C, such that the punch **504** has been fully pushed in with respect to the die **502**.

As illustrated in FIG. **5**, the hat-shaped cross-section component manufacturing apparatus **500** includes the die **502** that has a shape including respective outer surface side profiles of vertical walls **501***a*, **501***b*, and outward extending flanges **501***d*, **501***e* of the curving component **501**, the pad **503** that has a shape including the outer surface side profile of a top plate **501***c*, the punch **504** that is disposed facing the die **502** and the pad **503** and that has a shape including respective inner surface side profiles of the top plate **501***c* and the vertical walls **501***a*, **501***b* of the curving component **501**, and the blank holder **505**, serving as a holder, with a shape including inner surface side profiles of the outward extending flanges **501***d*, **501***e*.

As illustrated in FIG. **6**A to FIG. **6**D, the die **502** is disposed at an upper side of the punch **504**, and a central portion in the short direction (the left-right direction on the page) of the die **502** is formed with an opening **502***a* opening toward the punch **504** side. Inner walls of the opening **502***a* of the die **502** configure forming faces including the profile of the outer surfaces of the vertical walls **501***a*, **501***b* (see FIG. **5**) of the curving component **501**. Moreover, end faces on the blank holder **505** side of both die **502** short direction side portions configure forming faces including the profile of the faces on the vertical wall **501***a*, **501***b* sides of the outward extending flanges **501***d*, **501***e* of the curving component **501** (see FIG. **5**). A pad press device **506**, described later, is fixed to the closed end (upper end) of the opening **502***a* formed in the die **502**. Moreover, the die **502** is coupled to a mover device **509** such as a gas cushion, a hydraulic device, a spring, or an electric drive device. Actuating the mover device **509** enables up-down direction movement of the die **502**.

The pad **503** is disposed inside the opening **502***a* formed in the die **502**. The pad **503** is coupled to the pad press device **506**, this being a gas cushion, a hydraulic device, a spring, an electric drive device, or the like. A face on the die **502** side of the pad **503** configures a forming face including the profile of the outer surface of the top plate **501***c* (see FIG. **5**) of the curving component **501**. When the pad press device **506** is actuated, the pad **503** is pressed toward the punch **504** side, and a central portion **601***a* in the short direction (the left-right direction on the page) of the metal stock sheet **601** is pressed and gripped between the pad **503** and the punch **504**.

The punch **504** is formed by a protruding shape toward the pad **503** side at a location in the lower mold that faces the pad **503** in the up-down direction. Blank holder press devices **507**, described later, are fixed at the sides of the punch **504**. Outer faces of the punch **504** configure forming faces including the profile of the inner surfaces of the vertical walls **501***a*, **501***b* and the top plate **501***c* (see FIG. **5**) of the curving component **501**.

The blank holder **505** is coupled to the blank holder press devices **507**, serving as holder press devices, these being gas cushions, hydraulic devices, springs, electric drive devices, or the like. Die **502** side end faces of the blank holder **505** configure forming faces including the profile of faces of the outward extending flanges **501***d*, **501***e* of the curving component **501** on the opposite side to the vertical walls **501***a*, **501***b* (see FIG. **5**). When the blank holder press devices **507** are actuated, the blank holder **505** is pressed toward the die **502** side, and both short direction side portions **601***b*, **601***c* of the metal stock sheet **601** are pressed and gripped.

Next, explanation follows regarding a pressing process of the metal stock sheet **601** by the hat-shaped cross-section component manufacturing apparatus **500** described above.

First, as illustrated in FIG. **6**A, the metal stock sheet **601** is disposed between the die **502** and pad **503**, and the punch **504** and blank holder **505**.

Next, as illustrated in FIG. **6**B, the central portion **601***a* of the metal stock sheet **601**, namely a portion of the metal stock sheet **601** that will form the top plate **501***c* (see FIG. **5**), is pressed against the punch **504** by the pad **503**, and pressed and gripped between the two. Both side portions **601***b*, **601***c* of the metal stock sheet **601**, namely respective portions of the metal stock sheet **601** that will form the vertical walls **501***a*, **501***b* and the outward extending flanges **501***d*, **501***e* (see FIG. **5**), are pressed against the die **502** by the blank holder **505**, and are pressed and gripped between the two.

The pad press device **506** and the blank holder press devices **507** are actuated, such that the central portion **601***a* and both side portions **601***b*, **601***c* of the metal stock sheet **601** are pressed with a specific pressing force and gripped. The central portion **601***a* and both side portions **601***b*, **601***c* of the metal stock sheet **601** are formed into curved profiles to follow the curved profiles of the pressing curved faces as a result.

In this state, the mover device **509** is actuated, and the blank holder **505** and the die **502** are moved relatively in a direction away from the die **502** toward the blank holder **505**

(toward the lower side), thereby forming the curving component **501**. The pad press device **506** and the blank holder press devices **507** retract in the up-down direction accompanying lowering of the die **502**. When the pad press device **506** and the blank holder press devices **507** retract in the up-down direction, the central portion **601***a* and both side portions **601***b*, **601***c* of the metal stock sheet **601** are pressed with a specific pressing force.

As illustrated in FIG. **6**C, the metal stock sheet **601** gripped between the die **502** and the blank holder **505** flows into the opening **502***a* between the punch **504** and the die **502** accompanying the movement of the blank holder **505** and the die **502**, thereby forming the vertical walls **501***a*, **501***b* (see FIG. **5**).

Then, as illustrated in FIG. **6**D, the blank holder **505** and the die **502** move by a specific distance, and forming is completed at the point when the height of the vertical walls **501***a*, **501***b* reaches a specific height.

Note that in the example illustrated in FIG. **6**A to FIG. **6**D, the curving component **501** is formed by moving the blank holder **505** and the die **502** in a stationary state of the punch **504** and the pad **503**. However, the present invention is not limited thereto, and the curving component **501** may be formed in the following manner.

FIG. **7** illustrates a hat-shaped cross-section component manufacturing apparatus **600** according to another exemplary embodiment for manufacturing the curving component **501**. FIG. **8**A is a cross-section illustrating the manufacturing apparatus illustrated in FIG. **7** at a stage at the start of processing. FIG. **8**B is a cross-section illustrating a stage at which the metal stock sheet **601** is gripped and restrained between a die **602** and pad **603**, and a blank holder **605** and punch **604** of the manufacturing apparatus illustrated in FIG. **7**. FIG. **8**C is a cross-section illustrating a stage at which the punch **604** has been pushed in from the stage illustrated in FIG. **8**B. FIG. **8**D is a cross-section illustrating a state in which the punch **604** has been pushed in further from the stage illustrated in FIG. **8**C, such that the punch **604** has been fully pushed in with respect to the die **602**.

In contrast to the hat-shaped cross-section component manufacturing apparatus **500** illustrated in FIG. **5** and FIG. **6**A to FIG. **6**D, in the hat-shaped cross-section component manufacturing apparatus **600** the blank holder **605** and the punch **604** are provided at an upper side of the die **602** and the pad **603**. In the hat-shaped cross-section component manufacturing apparatus **600**, the curving component **501** is formed by moving (lowering) the pad **603** and the punch **604** in a state in which the die **602** is fixed, and the blank holder **605** presses the metal stock sheet **601** against the die **602** without moving. Note that in both the hat-shaped cross-section component manufacturing apparatus **600** and the hat-shaped cross-section component manufacturing apparatus **500**, the relative movement within the mold is the same, and the metal stock sheet **601** can be formed into the curving component **501** by using whichever of the hat-shaped cross-section component manufacturing apparatuses **500**, **600**.

Next, explanation follows regarding a removal process of the curving component **501** from the hat-shaped cross-section component manufacturing apparatus **500** (mold) after pressing the metal stock sheet **601**, namely after forming the curving component **501**.

As illustrated in FIG. **9**A to FIG. **9**C, when the curving component **501** is demolded from the hat-shaped cross-section component manufacturing apparatus **500** (mold), it is necessary to move the die **502** upward from the state in FIG. **6**D and away from the punch, **504** to create a gap within the mold. When this is performed, as illustrated in FIG. **9**B and FIG. **9**C, while the pad **503** and the blank holder **505** are being pressed by the respective pad press device **506** and the blank holder press devices **507**, the curving component **501** bears pressing force directed in mutually opposing directions from the pad **503** and the blank holder **505** during demolding, deforming and crushing the curving component **501** by the pressing forces directed in opposite directions, as illustrated in FIG. **9**C.

Accordingly, as illustrated in FIG. **10**A to FIG. **10**C, after the metal stock sheet **601** has been formed into the curving component **501**, configuration is made such that the die **502** and the pad press device **506** are separated from the blank holder **505** in a state in which the blank holder **505** does not move relative to the punch **504**, and the blank holder **505** does not press the formed curving component against the die **502**. Accordingly, although the pad press device **503** presses the curving component until the pad press device **506** has extended to the end of its stroke, after the pad press device **506** has moved a specific distance or greater and the pad press device **506** has fully extended to the end of its stroke, the pad **503** is separated from the punch **504**. The curving component **501** therefore does not bear pressing from the pad **503** and the blank holder **505** at the same time, and the die **502** and the pad **503** can be separated from the blank holder **505** and the punch **504**, thereby enabling the curving component **501** to be removed from the mold without being deformed.

As another exemplary embodiment, as illustrated in FIG. **11**A to FIG. **11**C, after forming the metal stock sheet into the curving component **501**, the pad **503** is not moved relative to the die **502**, and the pad **503** does not press the formed curving component **501** against the punch **504**. In this state, when the pad **503** and the die **502** are separated from the blank holder **505** and the punch **504**, the blank holder **505** press the curving component until the blank holder press devices **507** extend to the end of their stroke. The blank holder **505** is then separated from the die **502** after the die **502** has moved a specific distance or greater and the blank holder press devices **507** have fully extended to the end of their stroke. This thereby enables the die **502** and pad **503**, and the blank holder **505** and punch **504**, to be separated without the curving component **501** bearing pressure from the pad **503** and the blank holder **505** at the same time, thereby enabling the curving component **501** to be removed from the mold.

Yet another exemplary embodiment is one in which, although not illustrated in the drawings, after forming the metal stock sheet into the curving component **501**, the pad **503** does not move relative to the blank holder **505**, and the pad **503** does not press the formed curving component against the punch **504**. In this state, when the pad **503**, die **502**, and blank holder **505** are separated from the punch **504**, the blank holder **505** presses the curving component **501** until the blank holder press devices **507** have extended to the end of their strokes. After the die **502** moves a specific distance or greater and the blank holder press devices **507** have fully extended to the end of their stroke, the blank holder **505** is then separated from the die **502**. This thereby enables the die **502** and pad **503** to be separated, from the blank holder **505** and punch **504**, without the curving component **501** bearing pressure from the pad **503** and the blank holder **505** at the same time, thereby enabling the curving component **501** to be removed from the mold.

Accordingly, in order to prevent damage to the curving component **501** during demolding, the hat-shaped cross-section component manufacturing apparatus **500** may be provided with a pressure limiting device capable of prevent-

ing the curving component **501** from bearing pressure from the pad **503** and the blank holder **505** at the same time.

Explanation follows regarding a specific configuration of a pressure limiting device provided to the hat-shaped cross-section component manufacturing apparatus **500**.

Pressure Limiting Device **510** Configuration

As illustrated in FIG. **12**A, the pressure limiting device **510** includes floating blocks **514** that are formed in rectangular block shapes, and serve as a pressure limiting section. The pressure limiting device **510** further includes a pair of holding arms **511**, serving as a retention section, that engage with the floating blocks **514** when forming of the curving component **501** is completed, thereby integrating the floating blocks **514** together with the blank holder **505**, namely, enabling the floating blocks **514** to move as a unit with the blank holder **505**. The pressure limiting device **510** further includes a retention release section **515** that releases retention of the floating blocks **514** by the holding arms **511**.

As illustrated in FIG. **12**B, two of the floating blocks **514** are provided on a base plate **508**. Note that in the present exemplary embodiment, explanation is given regarding a case in which two of the floating blocks **514** are employed; however, a single floating block may be employed depending on the shape and dimensions of the curving component **501** to be formed, or three or more floating blocks may be employed in cases in which there is a large pad load.

The two floating blocks **514** are formed using a block shaped steel material having a rigidity and strength so as not to buckle or plastically deform even when bearing the pressing force of the pad **503**. The two floating blocks **514** are respectively disposed on the base plate **508** on both length direction sides of the punch **504**, and are capable of ascending and descending. As illustrated in FIG. **12**A, a location on an upper side of each floating block **514** configures a block upper portion **514***a* with a width dimension that is a substantially uniform dimension as viewed from the side, and a location on a lower side of each floating block **514** configures a block lower portion **514***b* that, as viewed from the side, has a width dimension that is a dimension of the width dimension of the block upper portion **514***a* or greater, and that is formed such that its width dimension gradually narrows on progression toward the upper side. The retention release section **515**, described later, is provided to the block upper portion **514***a*. As illustrated in FIG. **12**C, FIG. **12**D, and FIG. **12**E, both length direction end portions of the blank holder **505** are formed with block upper portion insertion holes **505***a* through which the block upper portions **514***a* pass. As illustrated in FIG. **12**A, a lower end portion of the block lower portion **514***b* is formed with recess shaped engaged-with portions **514***c* with which engagement portions **511***c* of the holding arms **511**, described later, engage.

As illustrated in FIG. **12**A and FIG. **12**D, the pair of holding arms **511** are disposed inside holding arm housing holes **505***b* formed integrally to the block upper portion insertion holes **505***a*. Moreover, the pair of holding arms **511** each include a swinging block **511***a* formed in a block shape with its length direction in the up-down direction as viewed from the side, and a rod shaped extension portion **511***b* extending from the swinging block **511***a* toward the upper side. A lower end portion of each swinging block **511***a* is configured by a hook shaped engagement portion **511***c* that engages with the engaged-with portion **514***c* formed to the block lower portion **514***b* of the floating block **514**. An upper portion of the swinging block **511***a* is supported by the blank holder **505** through a pin **516**, so as to be capable of swinging.

At the forming bottom dead center, namely, on completion of forming the curving component **501** (see FIG. **6**D), the swinging blocks **511***a* swing toward one side (swing in the direction of the arrows C**1**) as illustrated in FIG. **12**A, such that the engagement portions **511***c* of the swinging blocks **511***a* engage with the engaged-with portions **514***c* of the floating block **514**. As illustrated in FIG. **12**D, this thereby enables the floating block **514** to move together as a unit with the blank holder **505**. Moreover, as illustrated in FIG. **12**A, in the present exemplary embodiment, a pair of springs **512** to which rollers **513** are attached are fixed to the base plate **508** (see FIG. **12**B). At the forming bottom dead center, the pair of springs **152** press the swinging blocks **511***a* of the holding arms **511** through the rollers **513**, such that the swinging blocks **511***a* swing toward the one side (swing in the arrow C**1** direction), and the engagement portions **511***c* of the swinging blocks **511***a* engage with the engaged-with portions **514***c* of the floating block **514**. Part of the pad **503** is in contact with an upper end portion of the floating block **514** as the floating block **514** ascends together with the blank holder **505**. Accordingly, movement of the pad **503** and the punch **504** in approaching directions is prevented by the pressure limiting device **510**, and, during demolding, either the formed curving component **501** (see FIG. **6**D) is not pressed between the pad **503** and the blank holder **505**, or only a small amount of pressure acts thereon.

From the state illustrated in FIG. **12**A, the swinging blocks **511***a* then swing toward another side (swing in the direction of the arrows C**2**), thereby releasing the engagement between the engagement portions **511***c* of the swinging blocks **511***a* and the engaged-with portions **514***c* of the floating block **514**. In the present exemplary embodiment, part of the retention release section **515**, described later, presses the extension portions **511***b* of the holding arms **511**, such that the swinging blocks **511***a* swing toward the another side (swing in the direction of the arrows C**2**), thereby releasing the engagement between the engagement portions **511***c* of the swinging blocks **511***a* and the engaged-with portions **514***c* of the floating block **514**.

The retention release section **515** includes a tilt plate **518**. The tilt plate **518** is disposed inside an opening **514***d* that opens onto a side of the block upper portion **514***a*, and is supported at intermediate portions by pins **517**, so as to be capable of tilting. At an upper side of the tilt plate **518**, a pad load transmission rod **519** is provided disposed inside an opening **514***e* that places an upper end of the block upper portion **514***a* in communication with the opening **514***d*. A coil spring **520** is provided at a lower side of the tilt plate **518**.

One end portion **518***a* of the tilt plate **518** projects out from the floating block **514** toward the side, and the one end portion **518***a* of the tilt plate **518** is disposed at an upper side of the extension portions **511***b* of the holding arms **511** when the floating blocks **514** and the blank holder **505** are in an integrated state, as illustrated in FIG. **12**A and FIG. **12**D.

The pad load transmission rod **519** is disposed at an upper side of another end portion **518***b* of the tilt plate **518**. The pad load transmission rod **519** is pressed toward the lower side by the pad **503**, such that the pad load transmission rod **519** presses the other end portion **518***b* of the tilt plate **518**. Accordingly, in a state in which the pad **503** contacts an upper end portion of the block upper portion **514***a*, the one end portion **518***a* of the tilt plate **518** moves away from the extension portions **511***b* of the holding arms **511**. The holding arms **511** are then able to swing in the arrow C**1** directions, enabling, as illustrated in FIG. **12**A, the engage-

ment portions **511***c* of the holding arms **511** to engage with the engaged-with portions **514***c* of the floating block **514**.

The coil spring **520** is disposed at a lower side of the other end portion **518***b* of the tilt plate **518**, and the coil spring **520** biases the other end portion **518***b* of the tilt plate **518** toward the upper side. Accordingly, in a state in which the pad **503** has moved away from the upper end portion of the block upper portion **514***a*, the one end portion **518***a* of the tilt plate **518** tilts toward the side of the extension portions **511***b* of the holding arms **511**, and the one end portion **518***a* of the tilt plate **518** presses the extension portions **511***b* of the holding arms **511**. Accordingly, the swinging blocks **511***a* swing in the arrow C**2** directions against the pressing force of the rollers **513** from the springs **512**, releasing the engagement between the engagement portions **511***c* of the swinging blocks **511***a* and the engaged-with portions **514***c* of the floating block **514**. Namely, retention of the floating block **514** by the holding arms **511** is released.

Next, explanation follows regarding operation of the pressure limiting device **510**.

FIG. **13**A and FIG. **14**A illustrate a state of the curving component **501** prior to the start of forming. At the timing illustrated in FIG. **13**B and FIG. **14**B, the metal stock sheet **601** is gripped by the pad **503** and punch **504**, and the die **502** and blank holder **505**. Note that in the present exemplary embodiment, adjustment blocks **521** are interposed between the pad **503** and the floating blocks **514**. Clearance is thereby adjusted according to variations in sheet thickness of the metal stock sheet **601** and the like. In the present exemplary embodiment, respective adjustment blocks **521** are fixed to both length direction end portions of the pad **503**. In the following explanation, contact between the adjustment blocks **521** and the floating blocks **514** includes cases in which the pad **503** contacts the floating blocks **514** directly. Moreover, at the timing illustrated in FIG. **13**B and FIG. **14**B, both length direction end portions of the pad **503** are in contact with the upper end portions of the floating blocks **514** through the adjustment blocks **521**.

At the timing illustrated in FIG. **13**C and FIG. **14**C, the metal stock sheet **601** gripped between the die **502** and the blank holder **505** flows into the opening **502***a* between the punch **504** and the die **502**, and the vertical walls **501***a*, **501***b* of the curving component **501** is formed, as the blank holder **505** and the die **502** move toward the lower side. Then, at the timing illustrated in FIG. **13**D and FIG. **14**D, the blank holder **505** and the die **502** move to the forming bottom dead center, and forming of the curving component **501** is completed. In this state, both length direction end portions of the pad **503** are in contact with the upper end portions of the floating blocks **514** through the adjustment blocks **521**.

When the blank holder **505** has moved to the forming bottom dead center, the adjustment blocks **521** press down the tops of the pad load transmission rods **519** in the arrow Z direction, as illustrated in FIG. **12**A, such that the one end portion **518***a* of each tilt plate **518** separates from the extension portions **511***b* of the holding arms **511**, and the engagement portions **511***c* of the holding arms **511** engage with the engaged-with portions **514***c* of the floating blocks **514** under the biasing force of the springs **512**. The blank holder **505** is thereby coupled together with the floating blocks **514**, and in the subsequent demolding process, the blank holder **505** and the floating blocks **514** ascend together as a unit.

After reaching the forming bottom dead center, as illustrated in FIG. **13**E and FIG. **13**F, and in FIG. **14**E and FIG. **14**F, when the blank holder **505** ascends together with the floating blocks **514**, the top plate **501***c* of the curving component **501** that was hitherto in contact with an upper face of the punch **504** separates from the upper face of the punch **504**. When the blank holder **505** is ascending together with the floating block **514**, the floating blocks **514** are coupled to the blank holder **505** through the holding arms **511**, and the pad **503** and the blank holder **505** are prevented from moving relative to each other in approaching directions along the up-down direction. During the demolding process, even if the formed curving component **501** bears force along the approaching directions of the pad press device **506** and the blank holder press devices **507** (see FIG. **11**B) due to the force thereof, the formed curving component **501** is not pressed between the pad **503** and the blank holder **505** to such an extent that it is deformed.

As illustrated in FIG. **13**G and FIG. **14**G, the curving component **501** can be removed when the die **502** ascends to its top dead center. When the die **502** reaches the top dead center, and the pad **503** separates from the floating blocks **514**, namely when the adjustment blocks **521** attached to the pad **503** separate from the floating blocks **514**, as illustrated in FIG. **12**D, the one end portion **518***a* of each tilt plate **518** presses the extension portions **511***b* of the holding arms **511** under the biasing force of the coil spring **520**. Accordingly, the swinging blocks **511***a* swing in the arrow C**2** directions, and the engagement between the engagement portions **511***c* of the swinging blocks **511***a* and the engaged-with portions **514***c* of the floating block **514** is released. Then, as illustrated in FIG. **13**G, the floating blocks **514** drop through the block upper portion insertion holes **505***a* and the holding arm housing holes **505***b* (see FIG. **12**C), and return to their home positions on the base plate **508** (see FIG. **12**B).

As described above, in the present exemplary embodiment, employing the hat-shaped cross-section component manufacturing apparatus **500** provided with the pressure limiting device **510** enables the formed curving component **501** to be demolded without sustaining damage. The hat-shaped cross-section component manufacturing apparatus **500** of the present exemplary embodiment moreover enables the curving component **501** to be demolded without any increase in cycle time compared to conventional manufacturing apparatus that is not provided with the pressure limiting device **510** described above. This thereby enables low cost mass production of the curving component **501**.

In the present exemplary embodiment, explanation has been given regarding an example in which the floating blocks **514** and the blank holder **505** are configured capable of moving together as a unit by employing the holding arms **511**. However, the present invention is not limited thereto. Namely, other mechanisms may similarly be applied as long as they are mechanisms capable of retaining the floating blocks **514** at the forming bottom dead center, and of separating the floating blocks **514** after the pad has separated from the two floating blocks **514**. Examples of such configurations include:

(1) Latch types (types in which latch arms are provided to the floating blocks **514**);

(2) Push pin types (methods in which sprung pins enter fixing holes from the floating blocks **514** or the blank holder **505** and form a unit therewith);

(3) Gear types (gears installed in the floating blocks **514** are retained by pressing by the pad **503**, and lock with gears installed to the blank holder **505**); and

(4) Cam types (installed with a cam that moves horizontally accompanying downward movement of the blank holder **505**, such that a leading end of the cam locks the floating block **514**).

In the present exemplary embodiment, explanation has been given regarding an example in which the hook shaped engagement portions **511***c* formed to the swinging blocks **511***a* of the holding arms **511** engage with the engaged-with portions **514***c* formed to the block lower portion **514***b* of each floating block **514**; however, the present invention is not limited thereto. For example, as illustrated in FIG. **15**A and FIG. **15**B, engagement recesses **511***d*, serving as engagement portions formed to the swinging blocks **511***a* of the holding arms **511**, may engage with engagement protrusions **514***f*, serving as engaged-with portions, formed to the block lower portion **514***b* of each floating block **514**.

In the present exemplary embodiment, explanation has been given regarding an example in which the retention release section **515** is provided to the block upper portion **514***a* of each floating block **514**. However, the present invention is not limited thereto. For example, as illustrated in FIG. **16**A, a retention release section **522** having the same function as the retention release section **515** described above may be provided to frame portions **508***a* (see also FIG. **12**B) so as to extend up from both length direction end portions of the base plate **508**, serving as a base section. Each retention release section **522** is configured including a tilting portion **524** that is tiltably supported by the frame portion **508***a* of the base plate **508** through a bracket **523**, and a coil spring **525** that biases a leading end side **524***a* of the tilting portion **524** toward the lower side. In the retention release section **522**, when the blank holder **505** and the die **502** have risen a specific distance from the forming bottom dead center illustrated in FIG. **16**B, the extension portions **511***b* of the holding arms **511** contact the leading end side **524***a* of the tilting portion **524**, and the extension portions **511***b* of the holding arms **511** are pressed toward the lower side by the leading end side **524***a* of the tilting portion **524**. Accordingly, as illustrated in FIG. **16**C and FIG. **16**D, the engagement between the engagement portions **511***c* of the swinging blocks **511***a* and the engaged-with portions **514***c* of the floating block **514** is released.

In the present exemplary embodiment, explanation has been given regarding an example in which the formed curving component **501** is suppressed from being pressed between the pad **503** and the blank holder **505** by part of the pad **503** contacting the upper end portion of the floating blocks **514** through the adjustment blocks **521**; however, the present invention is not limited thereto. For example, the formed curving component **501** may be suppressed from being pressed between the pad **503** and the blank holder **505** by a member that moves together with the pad **503** contacting the upper end portion of the floating block **514**.

Operation and Advantageous Effects of Present Exemplary Embodiment, Suitable Values etc. for Various Parameters

Next, explanation follows regarding operation and advantageous effects of the present exemplary embodiment, and suitable values for various parameters, and the like.

As illustrated in FIG. **12**A to FIG. **14**G, in the present exemplary embodiment, the hat-shaped cross-section component manufacturing apparatus **500** is provided with the pressure limiting device **510** described above. During demolding, the curving component **501** can be removed from the mold (the blank holder **505**, the die **502**, the punch **504**, and the pad **503**) in a state in which the formed curving component **501** is prevented by the pressure limiting device **510** from being pressed by the pad **503** and the blank holder **505** at the same time.

In the present exemplary embodiment, during formation of the vertical walls **501***a*, **501***b* of the curving component **501** by the hat-shaped cross-section component manufacturing apparatus **500** illustrated in FIG. **5** to FIG. **6**D, the portion of the metal stock sheet **601** that will form the top plate **501***c* is pressed and gripped by the pad **503** and the punch **504**. Provided that the pressing force is sufficient, the portion of the metal stock sheet **601** that will form the top plate **501***c* cannot be deformed in its thickness direction during the forming process, enabling the occurrence of creases at this portion to be suppressed. Moreover, the portions of the metal stock sheet **601** that will form the outward extending flanges **501***d*, **501***e* are also pressed and gripped by the blank holder **505** and the die **502**, such that provided that the pressing force is sufficient, the portions of the metal stock sheet **601** that will form the outward extending flanges **501***d*, **501***e* cannot be deformed in the thickness direction, enabling the occurrence of creases at these portions to be suppressed.

However, if the above pressing forces are insufficient, deformation of the metal stock sheet **601** in the thickness direction cannot be prevented, and creases will occur at the portion of the metal stock sheet **601** that will form the top plate **501***c* and at the portions of the metal stock sheet **601** that will form the outward extending flanges **501***d*, **501***e*. The sheet thickness employed in structural members configuring automotive vehicle body framework (such as front side members) is generally from 0.8 mm to 3.2 mm. When a steel sheet with tensile strength of from 200 MPa to 1600 MPa is formed by using the hat-shaped cross-section component manufacturing apparatus **500** illustrated in FIG. **5** to FIG. **6**D, the above pressing forces are preferably 0.1 MPa or greater.

FIG. **17**A illustrates stress arising in the vertical walls **501***a*, **501***b* of the curving component **501**. FIG. **17**B and FIG. **17**C illustrate shear creasing arising in the vertical walls **501***a*, **501***b* of the curving component **501**.

In FIG. **17**A, it can be seen that deformation of the portions of the metal stock sheet **601** that will form the vertical walls **501***a*, **501***b* from before to after forming the vertical walls **501***a*, **501***b* of the curving component **501** is mainly shear deformation. Forming the vertical walls **501***a*, **501***b* of the curving component **501** accompanied by deformation that is mainly shear deformation suppresses a reduction in the sheet thickness of the vertical walls **501***a*, **501***b* compared to the sheet thickness of the metal stock sheet **601**. This thereby enables the occurrence of creasing and cracking in the vertical walls **501***a*, **501***b* to be suppressed.

During formation of the vertical walls **501***a*, **501***b*, the portions of the metal stock sheet **601** that will form the vertical walls **501***a*, **501***b* undergo compression deformation in the minimum principal strain direction of the shear deformation. Accordingly, as illustrated in FIG. **17**B and FIG. **17**C, shear creasing W occurs in the vertical walls **501***a*, **501***b* of the curving component **501** if the clearance between the die **602** and the punch **604** becomes large. In order to suppress such shear creasing W, it is effective to reduce the clearance between the die **602** and the punch **604** such that the clearance is brought close to the sheet thickness of the metal stock sheet **601** during formation of the vertical walls **501***a*, **501***b*.

As illustrated in FIG. **18**A to FIG. **18**D, it is necessary for an internal angle θ formed between the respective vertical walls **501***a*, **501***b* and the top plate **501***c* to be 90° or greater so as not to have a negative mold angle during forming. However, since the clearance during initial forming increases if too far over 90°, an angle close to 90° that is 90° or greater is advantageous. When a steel sheet with a sheet thickness of from 0.8 mm to 3.2 mm, and tensile strength of from 200 MPa to 1600 MPa, that is generally employed in

structural members configuring automotive vehicle body framework, is used to form a component in which the height of the vertical walls **501***a*, **501***b* is 200 mm or less, the internal angle formed between the top plate **501***c* and the vertical walls **501***a*, **501***b* is preferably from 90° to 92°, and a clearance b between the die **502** and the punch **504** at the portions forming the vertical walls **501***a*, **501***b* at the point when forming of the vertical walls **501***a*, **501***b* is completed is preferably from 100% to 120% of the sheet thickness of the metal stock sheet **601**.

Next, explanation follows regarding results of investigation into the occurrence of creasing in the curving component **501**, using parameters of (1) the angle formed between the vertical walls **501***a*, **501***b* and the top plate **501***c*, (2) mold clearance (varying the sheet thickness t with respect to the fixed clearance b), (3) the pressure applied to the pad **503** (pad pressure), (4) the pressure applied to the blank holder **505** (holder pressure), and (5) the tensile strength of the material.

FIG. **19**A is a perspective view illustrating the curving component **501**. FIG. **19**B is a plan view illustrating the curving component **501** in FIG. **19**A, as viewed from above. FIG. **19**C is a side view of the curving component **501** in FIG. **19**A. FIG. **19**D is a cross-section illustrating a cross-section of the curving component **501** taken along the line A-A in FIG. **19**C. FIG. **20** is a cross-section of the mold.

TABLE 1

	CASE	Tensile Strength of Material (MPa)	Sheet Thickness t (mm)	θ (°)	Clearance b (mm)	b/t	Pad Pressure (MPa)	Blank Holder Pressure (MPa)	Creasing
Example	1	980	1.8	90	1.8	1.00	5.83	2.50	Absent
	2	980	1.8	91	1.8	1.00	5.83	2.50	Absent
	3	980	1.8	92	1.8	1.00	5.83	2.50	Absent
	4	980	1.8	95	1.8	1.00	5.83	2.50	Somewhat present
	5	980	1.8	80	1.8	1.00	5.83	2.50	Somewhat present
	6	980	1.6	90	1.8	1.13	5.83	2.50	Absent
	7	980	1.4	90	1.8	1.29	5.83	2.50	Somewhat present
	8	980	1.2	90	1.8	1.50	5.83	2.50	Somewhat present
	9	980	1.0	90	1.8	1.80	5.83	2.50	Somewhat present
	10	440	1.6	90	1.8	1.13	2.33	1.50	Absent
	11	440	1.6	90	1.8	1.13	1.17	1.50	Absent
	12	440	1.6	90	1.8	1.13	0.58	1.50	Absent
	13	400	1.6	90	1.8	1.13	0.09	1.50	Somewhat present
	14	440	1.6	90	1.8	1.13	3.50	1.00	Absent
	15	440	1.6	90	1.8	1.13	3.50	0.75	Absent
	16	440	1.6	90	1.8	1.13	3.50	0.09	Somewhat present
	17	1310	1.8	90	1.8	1.00	5.83	2.50	Absent
	18	590	1.6	90	1.8	1.13	3.50	1.50	Absent
	19	440	1.6	90	1.8	1.13	2.33	1.50	Absent

The angle θ in Table 1 is the internal angle θ formed between the vertical walls **501***a*, **501***b* and the top plate **501***c*, as illustrated in FIG. **19**D. The clearance b in Table 1 is the gap between the pad **503** and the punch **504**, between the die **502** and punch **504**, and the die **502** and blank holder **505**, as illustrated in FIG. **20**.

Each of the Examples 1 to 19 in Table 1 are examples of the present exemplary embodiment. In Table 1, "somewhat present" refers to the occurrence of creasing at an acceptable level. (1) Nos. 1 to 5 examples of cases in which the angle formed between the vertical walls **501***a*, **501***b* and the top plate **501***c* was varied. (2) Nos. 6 to 9 are examples of cases in which the mold clearance, more specifically the sheet thickness t with respect to a fixed clearance b, was varied. (3) Nos. 10 to 13 are examples of cases in which the pressure applied to the pad **503** (pad pressure) was varied. (4) Nos. 14 to 16 are examples of cases in which the pressure applied to the blank holder **505** (holder pressure) was varied. (5) Nos. 17 to 19 are examples of cases in which the tensile strength of the material was varied. The presence or absence of creasing occurrence was investigated in curving components manufactured for each Example.

It can be seen from the above table that unacceptable creasing of the components did not occur in the curving component **501** within the range of parameters investigated.

Explanation has been given above regarding examples in which curving hat-shaped cross-section components (the curving component **501**) are formed using the hat-shaped cross-section component manufacturing apparatus **500** (see FIG. **5**). However, the present invention is not limited thereto. For example, the hat-shaped cross-section component manufacturing apparatus **500** may be used to form hat-shaped cross-section components that have a uniform cross-section along the length direction, and do not curve in side view or in plan view.

Explanation has been given regarding exemplary embodiments of the present invention; however, the present invention is not limited to the above, and obviously various modifications other than the above may be implemented.

The entire content of Japanese Patent Application No. 2013-221522, filed on Oct. 24, 2013, is incorporated by reference in the present specification.

The invention claimed is:

1. A hat-shaped cross-section component manufacturing apparatus comprising:

a die that includes a forming face that presses both side portions of a metal sheet, and that includes an opening;

a punch that is disposed facing the opening of the die, wherein the punch is disposed inside the opening when a mold is closed, and wherein the punch includes a forming face that presses a central portion of the metal sheet;

a pad that is disposed inside the opening formed in the die, wherein the pad includes a forming face that presses and grips the central portion of the metal sheet against the punch when the mold is closed so as to configure a forming face corresponding to the forming face of the punch;

a holder that is disposed outside the opening and facing the die and movable toward the die, wherein the holder includes a forming face that presses and grips both side portions of the metal sheet against the die when the mold is closed so as to configure a forming face corresponding to the forming face of the die; and

a pressure limiting device that includes:

floating blocks that are movable in a demolding direction with regard to the punch, the floating blocks being interposed between the pad and the holder and being configured to contact the pad in a state in which the holder and the die have moved to a forming bottom dead center, and

a pair of holding arms that are provided at the holder, the pair of holding arms engaging with the floating blocks when the holder moves to the forming bottom dead center, and engagement of the holding arms with the floating blocks being released when the pad separates from the floating blocks during demolding,

wherein the floating blocks are caused to move together with the holder during demolding after forming of a hat-shaped cross-section component having a hat-shaped cross-section, and pressing on the hat-shaped cross-section component by the pad and the holder is limited by the floating blocks, which are interposed between the pad and the holder.

2. The hat-shaped cross-section component manufacturing apparatus of claim **1**, wherein the pressure limiting device includes a retention release section that enables movement of the floating blocks relative to the holder once the holder has moved a specific distance.

3. The hat-shaped cross-section component manufacturing apparatus of claim **2**, wherein the retention release section releases the engagement between the holding arms and the floating blocks by contacting the holding arms.

4. The hat-shaped cross-section component manufacturing apparatus of claim **2**, wherein the retention release section is integrally provided at the floating blocks.

5. The hat-shaped cross-section component manufacturing apparatus of claim **2**, wherein the retention release section is provided at a base member to which the punch is fixed.

6. The hat-shaped cross-section component manufacturing apparatus of claim **1**, wherein:

the holding arms are supported on the holder so as to be capable of swinging;

the holding arms engage with the floating blocks by the holding arms swinging toward one side; and

the engagement between the holding arms and the floating blocks is released by the holding arms swinging toward another side.

7. A hat-shaped cross-section component manufacturing method employing the hat-shaped cross-section component manufacturing apparatus of claim **1**, the hat-shaped cross-section component manufacturing method comprising:

a forming process of forming the hat-shaped cross-section component by configuring a metal sheet that is curved up-down by gripping a central portion of the metal sheet between the punch and the pad, and gripping both side portions of the metal sheet between the die and the holder, and moving the holder and die, and the punch and pad, up-down relative to each other; and

a demolding process of demolding the hat-shaped cross-section component by moving one or both of the die or the holder in a demolding direction, in a state in which the pad and the floating blocks are in contact with each other.

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